UTKAL INSTITUTE OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES ON
RAILWAY & BRIDGE ENGINEERING
DIPLOMA, CIVIL ENGINEERING, 5TH SEMESTER

FACULTY NAME- Er. SRADHANJALI MOHANTY
DEPARTMENTY OF CIVIL ENGINEERING

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Recommended Books

Sl. No	Name of Authors	Titles of Book	Name of Publisher
1	Chandra & Agrawal	Railway Engineering	Oxford Publication
3	S.C.Sexena & S.P.Arora	A Text book of Railway Engineering	Dhanpat Rai Publications
4	S. C. Rangwala	Railway Engineering	Charotar Publication
5	S.P. Bindra	Bridge Engineering	Dhanpat Rai Publications

01 Railway Transportation Its Development

Role of Railways in Transportation:

- "Transportation is regarded as an index of economic, Social and Commercial progress of a Country". The transport industry, which undertakes nothing more than only movement of persons and things from one place to another, has created one of the most important activities of men in every stage of advanced civilisation.
- An adequate transportation is necessary for economic & social progress of a nation and the world as a whole.
- Land, water and Air have been used by the mankind for developing the transport modes like Railways, Highways, waterways, Airways, etc.

Historical Development of Railways in India:

1844: The first proposals for the construction of railways in India were submitted to East India company by Mr. R.M. Stephenson.

1849: Calcutta - Mirzapur (160 kms) by East India Company.

1853: first railway line between Bombay and thana (32 kms) was opened. It had 14 coaches and was driven by 3 engines.

1905: A Railway Board was established with one president and two members under the department of commerce and industries. → 1908 → 1922

1923: Nationalisation of Railways started.

1950: Regrouping of Railways was done and 6 Zones were formed.

Zonal Railways:

Zonal railways take care of railways business in their respective zones and are responsible for all management and planning works.

Zone	Headquarters
East Coast	Bhubaneswar
East Central	Hajipur
North Central	Allahabad
North Western	Jaipur
South Western	Bangalore
West central	Jabalpur

Production Units: or Manufacturing Units:

Manufacturing Units	Headquaters	functions
Chittaranjan Locomotive Works (CLW)	Chittaranjan	Manufacturer of Electric Locomotives
Diesel locomotive works (DLW)	Varanasi	Manufacturer of Diesel Locomotives
Integral Coach factory (ICF)	Chennai	Manufacturer of Coaches.
Diesel Components works (DCW)	Patiala	Manufacturer of Diesel Components
Rail Coach factory (RCF)	Kapurthala	Manufacture of Coaches.
Wheel & Axle plant (W&AP)	Bangalore	Manufacture of Wheels and Axles.

Advantages of Railways:

- Political Advantages:

(i) Railways have united the people of different castes, religions customs and traditions.

(ii) With the adequate network of railways, the central administration has become more easy and effective.

(iii) Railways have contributed towards development of a national mentality in the minds of people.

iv) the role of railways during emergencies in mobilising troops and war equipment has been very significant.
v) Railways have helped in the mass migration of the population.

Social Advantages:

(i) the feeling of isolation has been removed from the inhabitants of the Indian villages.
(ii) By travelling together in to the compartment without without any restriction of caste, the feeling of caste difference has disappeared considerably.
(iii) the social outlook of the masses has been broadened/ widen through railway journeys.
(iv) Railway has made it easier to reach places of religious importance.
(v) Railway provide a convenient and safe mode of transport for the Country.

Economic Advantages:

(i) Mobility of people has increased, thereby the congested areas can be relieved of congestion and the sparsely populated areas can be developed.
(ii) Mobility of Labour has contributed to industrial development.
(iii) During famines, railways have played the vital role in transporting food and clothing to the affected areas.
(iv) Growth of industries has been promoted due to transportation of raw materials through railways.
(v) Speedy distribution of finished product is achieved through railways.
(vi) Railways provide employment to millions of people & thus help in solving the unemployment problems of the country.
(vii) Trade developed due to railways thereby has increased the earnings and standard of living of Indian people.

(viii) Land values have increased due to industrial development which ultimately result in the increase of national wealth.

(ix) Due to mobility of products through railways, the Price Stabilisation of comodities could be possible.

(x) Commercial farming is very much helped by the railway network throughout the country.

Techno - Economic Advantages:

(i) Cost saving in transportation of long haul bulk traffic.

(ii) Energy - Efficiency (Railways consume one-seventh of fuel used by the road sector).

(iii) Environment friendliness.

(iv) Higher Safety (Fatal accidents one-tenth of road sector in India)

(v) Efficient land use and ease in capacity expansion. (comfort)

Classification of Indian Railways:

Railway board has classified the Indian Railway lines on the basis of the importance of route, traffic carried and maximum Permissible Speed on the routes, in to following 3 main catagories:

(I) Trunk Routes.

(II) Main Lines.

(III) Branch Lines

(I) Trunk Routes:

The following 6 routes of B.G. and 3 routes of M.G. have been classified as trunk routes:

On B.G:

1. Delhi - Mughalsarai - ~~Howarch~~ Howrah
2. ~~Dehl~~ Delhi - Kota - Mumbai
3. Delhi - Jhansi - Nagpur - chennai

4. Howrah - Bagpur - Mumbai
5. Mumbai - Guntakul - Chennai
6. Howrah - Vijayawada - Chennai.

On M.G :

1. Lucknow - Gorakhpur - Guwahati
2. Delhi - Jaipur - Ahmedabad
3. Chennai - Madurai - Trivandrum.

The following track standards for trunk routes have been specified:

Items	BG	MG
1. Max^m permissible speed	120 Km.p.h.	80 Km.p.h.
2. Rail section	52 kg/m or heavier	37.2 kg/m (i.e 75R)
3. Sleeper density	(n+7)	(n+7)
4. Ballast Cushion	25 cm below sleeper	25 cm below sleeper
5. Degree of curvature	$7\frac{1}{2}^{\circ}$	Suitable degree
6. Design speed for new track	160 km.p.h	100 km.p.h.

(2) Main Lines:

All lines other than trunk routes carrying 10 Gross Million Tonnes (GMT) per annum or more for B.G. and 2.5 G.M.T. or more for M.G. or where maximum permissible speed allowed is 100 kmph for B.G. & 75 kmph for MG are classified as main lines.

The following specifications have been laid down for main lines by Railway Board:

Items	B.G.	M.G
1. GMT / Annum	$\geqslant 10$	$\geqslant 2.5$
2. Max^m permissible speed	100 kmph	75 kmph
3. Track relaying period	20 years	30 years
4. Rail section	52 kg/m	37.2 kg/m
5. Design speed for new tracks	120 kmph	75 kmph

Branch line: (1 G.M.T = 1000 tonne)

Item	B.G	M.G
→ GMT / Annum	≥ 10 GMT	≥ 2.5 GMT
→ Permissible speed	≥ 100 kmph	≥ 75 kmph

Classification of Indian Railways based on Speed Criteria:

1. **Group 'A' Lines:**

They consists of those trunk routes on which the trains are running or are meant for running the trains at a speed of 160 kmph or more.

At present, the following routes come under this catagory:

(i) Central/New Delhi to Howrah by Rajdhani route.

(ii) New Delhi to Mumbai Central via Kota by Rajdhani Route.

(iii) New Delhi to chennai Central by Grand Trunk route.

(iv) Howrah to Mumbai V.T. via Nagpur.

(2) **Group 'B' Lines:**

They consists of those routes on which the trains with a Maximum Sanctioned Speed of 130 kmph are running or are intended to run. At present nearly 18 routes come under this catagory.

Ex: Allahabad to Bhusaval, Kalyan to chennai, Kharagpur to Vijayawada, Wadi to Kazipet, Howrah to New Jalpaiguri, Sitarampur to Mughalsarai, Kiul to Barharwa, Delhi to Kalka, Ambala to pathankot, Ambala to mughalsarai, Arkonam to coimbatore, Vadodara to Ahmedabad, Jalanpet to Bangalore.

(3) Group 'C' Lines:

They consist of all suburban routes of Mumbai, Calcutta and Delhi.

(4) Group 'D' Lines:

All other routes in the country where maximum permissible speed at present is 100 kmph.

(5) Group 'E' Lines:

the other routes and branch lines where the permissible Speed ~~at present~~ limits are less than 100 kmph.

RAILWAY TERMINOLOGY:

Railway Engineering:

Branch of engineering which deals with the construction and Maintenance of the railway track for safe and efficient movement of trains on it.

Rail: Rails are steel girders which provide the hard and Smooth surface for movement of wheels of a Locomotive and railway vehicles.

Sleepers: sleepers are the members laid transversely under the rails which are meant to Support the rails over them and transfer the Load from rails to ballast.

Ballast: Ballast is the granular material Packed under and around the sleepers to transfer loads from sleepers to ballast. It helps in providing elasticity of to the track.

Gauge: the gauge of a track in India is measured as the minimum distance between the inner running or gauge faces of the two rails.

Fish plate:

These plates, resembling in shape to a fish, are used to provide the continuity between the two rails at the rail-joints. they also provide the required gap for expansion and contraction of rail due to temperature variations. they are made of steel

02 PERMANENT WAY:

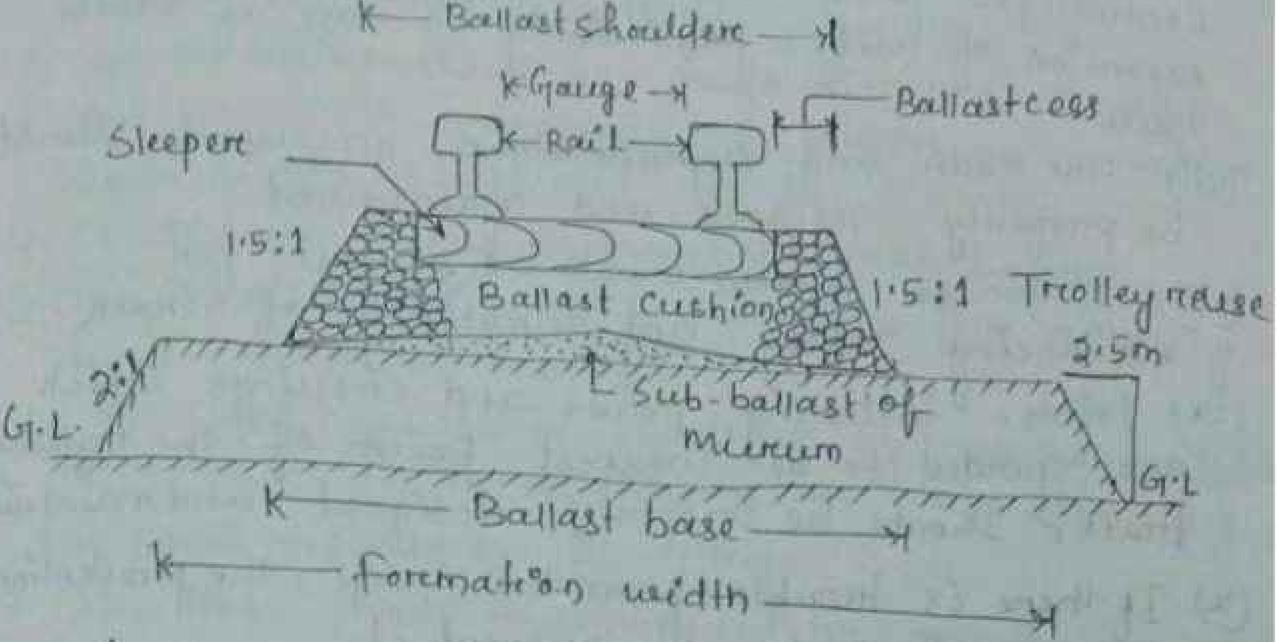
(i) The combination of rails, fitted on sleepers and resting on ballast and subgrade is called the railway track or permanent way. Sometimes temporary tracks are also laid for conveyance of earth and materials during construction works.

(ii) In a permanent way, the rails are joined in series by fish plates and bolts and then they are fixed to sleepers by different types of fastenings.
The sleepers properly spaced, resting on ballast, are suitably packed and boxed with ballast.
the layer of ballast rests on the prepared subgrade called the formation.

(iii) The rails act as girders to transmit the wheel load to the sleepers. the sleepers hold the rails in proper position with respect to the proper tilt, gauge and level, and transmit the load from rails to the ballast.

(iv) The ballast distributes the load over the formation and holds the sleepers in position.

(v) On curved tracks, super-elevation is maintained by ballast and the formation is levelled. Minimum ballast cushion is maintained at the inner rail, while the outer rail gets kept more ballast cushion. Additional quantity of ballast is provided on the outer ~~cess~~ ~~side~~ cess of each track for which the base width of the ballast is kept more than for a straight track.



(Typical cross-section of a permanent way on Embankment.)

Requirements of an Ideal permanent way:

(i) The gauge should be correct and uniform.

(ii) the rails should be in proper level. In a straight track, two rails must be at the same level. On curves, the outer rail should have proper superelevation and there should be proper transition at the junction of a straight and a curve.

(iii) The alignment should be correct; i.e., it should be free from kinks or irregularities.

(iv) The gradient should be uniform and as gentle as possible. Any change of gradient should be followed by a smooth vertical curve, to give smooth riding quality.

(v) The track should be resilient and elastic in order to absorb shocks and vibrations of running track.

(vi) The track should have enough lateral strength, so that alignment is maintained even due to effects of (a) side thrust on tangent lengths and

Centrifugal force on curves (b) lateral forces due to expansion of rails, particularly in case of welded rails.

(vii) The radii and superelevation on curves should be properly designed and maintained.

(viii) Drainage System must be perfect for enhancing safety and durability of track.

(ix) Joints, including points and crossings which are garded to be weakest points of the railway track, should be properly designed and maintained.

(x) If there is trouble from the creep, the preventionary measures should be to prevent it.

(xi) the various components of the track, i.e. the rails, fittings, sleepers, ballast and formation must fully satisfy the requirements for which they have been provided. If any component is lacking in fulfilling its requirements then either it should be improved or replaced.

(xii) there should be adequate provision for easy renewals and replacements.

(xiii) the track should be strong, low in initial cost as well as maintenance cost.

Capacity of a Railway Track:

- It is the number of trains that can be run Safely on a track per hours.
- the track capacity can be increased by the following ways:
  - (i) By achieving faster movement of trains on a track.
  - (ii) By decreasing the distance between successive trains.

Some of the general measures which can be taken to increase the track - capacity:

1. All the trains should be made to run at the same speed for which uniformity of gauges and traction should first be achieved in the country.
2. All sections should be made of equal length.
3. The speed of trains can be increased by adopting diesel or electric traction.
4. The speed can also be increased by making suitable improvements in the existing tracks and removing the speed restrictions, if any.
5. New lines should be constructed for operational and industrial purposes.

Gauges in Railway Track:

The 'Gauge' of a railway track is defined as the clear distance between inner or running faces of two track rails. The distance between the inner faces of a pair of wheels is called the "wheel gauge".

Types of Gauge	Gauge width
(i) Standard gauge / Broad gauge (B.G.)	1.67 m.
(ii) Meter gauge (M.G.)	1.0 m
(iii) Narrow gauge (N.G.)	0.762 m
(iv) Light gauge (L.G.)	0.61 m.

Selection of Gauge:

(1) Cost of construction :-

There is little increase in the initial cost if we select a broad gauge due to following reasons:

(a) The cost of bridges, tunnels, station building, staff quarters, signals, cabins and level crossings is the same for all the gauges.

(b) The cost of earthwork, (in making embankments and cuttings) ballast, sleepers, rails etc. would proportionally increase with increase in gauge width

(2) Volume and Nature of Traffic:

It is evident that with greater traffic volume & greater load carrying capacity, the trains should be run by a better traction technique or by better locomotives.

(3) Development of the Areas:

Narrow gauges can be used to develop the thinly populated areas by joining the under developed areas with developed or urbanised areas.

(4) Physical Features of the Country:

Use of Narrow gauge is warranted in hilly regions where broad and meter gauges are not possible due to steep gradient and sharp curves. In plains also, where high speed is not required and the traffic is light, N.G. is a right choice.

(5) Speed of movement:

The speed of a train is almost proportional to the gauge. Speed is the function of diameter of wheel, which in turn is limited by the gauge. The wheel diameter is generally 0.75 times that of the gauge. Lower speeds discourage the customers, and so for maintaining high speeds, the Broad gauge is preferred.

03 TRACK MATERIALS :

: RAIL :

Definition:

The rails on the track can be considered as steel girders for the purpose of carrying axle loads. They are made of high carbon steel to withstand wear and tear. Flat-footed rails are mostly used in railway track.

Functions of Rails:

- Rails provide a hard, smooth and unchanging surface for passage of heavy moving loads with a minimum friction between the steel rails and steel wheels.
- Rails bear the stresses developed due to heavy vertical loads, lateral and breaking forces and thermal stresses
- The rail material used is such that it gives minimum wear to avoid replacement charges and failures of rails due to wear.
- Rails transmit the loads to sleepers and consequently reduce pressure on ballast and formation below.

Requirements of Rails;

(i) They should be of proper composition of steel as given ~~above~~ below and should be manufactured by open hearth process.

for Ordinary Rails: Carbon (C) = 0.55 to 0.68 %.
Manganese (Mn) = 0.65 to 0.9 %.
Silicon (Si) = 0.05 to 0.3 %.
Sulphur (S) = 0.05 % or below.
Phosphorus (P) = 0.06 % or below.

(ii) The vertical stiffness should be high enough to transmit the load to several sleepers underneath the
The height of rail should, therefore, be adequate.

(iii) Rail should be capable enough to withstand against lateral forces. Large width of head & foot provide the rails with high lateral stiffness.

(iv) The head must be sufficiently deep to allow for an adequate margin of vertical wear. The wearing surface should be hard.

(v) Web of rails should be sufficiently thick to bear the load coming on it and should provide adequate flexural rigidity in horizontal plane.

(vi) Foot should be wide enough so that rails are stable against overturning, especially on curves.

(vii) Bottom of the head and top of the foot of rails should be so shaped as to enable the fish plates to transmit the vertical load efficiently from the head to the foot at rail joints.

(viii) Relative distribution of material of rail in head, web and foot must be balanced, for smooth transmission of loads.

(ix) The centre of gravity of the rail section must lie approximately at mid-height so that maximum tensile and compressive stresses are equal.

(x) The tensile strength of the rail piece should not be less than 72 kg/m^2.

(* Centre of gravity = Average location of the weight of an object.)

Types of Rail Section:

3 types of Rail sections is there. Such as:—

(i) Double headed rail (D.H. Rails)
(ii) Bull headed rails (B.H. Rails)
(iii) Flat footed rails (F.F. Rails)

Comparison of Rail Types:

Point of comparison	Flat footed Rails	Bull-headed Rails and Double-headed Rails.
1. Strength and Stiffness	These have more strength and stiffness for the same weight, both laterally and vertically.	These have less strength and stiffness.
2. Laying and Relaying	Fitting of these rails is simpler and so can be easily laid and relaid. No chairs required.	The fitting of these rails is difficult & time consuming as they are supported on chairs.
3. Arrangements at Points, crossings and at sharp curves	The arrangements are simpler and easy.	The arrangements are complicated & difficult.
4. Alignment and Stability of track	In this, Impact of rolling wheels affects the fittings and the loosening of fittings disturbs the alignment and gives less stability.	These rails when fitted on chairs, provide a more solid, smooth track and better stable alignment.
5. Initial cost	These rails require lesser and cheaper fastenings, so the initial cost is less.	These require more and costly fastenings & hence initial cost is more.
6. Rigidity	These rails can be used without bearing plates on sleepers as these rails are strong to withstand vertical loads. Hence they are more rigid.	These rails without chairs cannot be used on inferior types of sleepers, being less strong against vertical loads. Hence they are less rigid.

7. Inspection	Daily inspection is not necessary as no special risk is involved	In case of B.H. or D.H rails, daily inspection of wooden keys is necessary
8. Replacement of Rails	The dog spikes have to be taken out in addition to fish bolts and fish plates to change the rail. So replacement is difficult.	These rails can be changed easily by driving out the keys and taking out fish bolts & fish Plates, without disturbing sleepers.
9. Maintenance cost	the maintainance cost is less	It requires heavy maintenance cost
10. Suitability	these are more suitable due to better stability, economy, strength & stiffness.	these are more suitable when lateral loads are more important rather than vertical loads.

* **Chaires:** Chaires are used to hold the bull-headed & double-headed rails. these chairs are fixed to sleepers by round spikes.
* Dog spikes: Also called track spike, is often used to fasten T-shaped railway track to wooden sleepers, to secure a rail and tie plate to the ties in track.
* Fastening → Device that closes or secures something.

* [Minimum distance between two track is 3.5 m]

Advantages of flat footed rails:

(i) they have more strength and stiffness, both vertically and laterally, than bull headed rail

(ii) fitting of rails with sleepers is simpler, so they can be easily laid and relaid.

(iii) No chairs or keys are required as in case of bull headed rails.

(iv) In points & crossings, the arrangements are simpler than B.H. Rails.

Disadvantages:

(i) The fittings get loosened more frequently than in case of B.H. Rails. The impact of rolling wheels directly affects the fittings.

(ii) the straightening of bent rails, replacing of rails are difficult.

Advantages of bull headed Rails:

(i) they keep better alignment and give more solid and smoother track.

(ii) the rails are easily disconnected from sleepers as they have no direct connection with the latter.

(iii) the heavy chairs with larger bearing on sleepers give longer life to wooden sleepers & greater stability to the track.

Disadvantages:

(i) They require additional cost of iron chains.

(ii) They have less strength & stiffness.

(iii) they required heavy maintenance cost.

- Length of Rails

→ The rails of larger length are preferred to smaller length of rails, because they give more strength and economy for a railway track. The weakest point of a track is the joint between two rails.

→ Lesser the number of joints, lesser would be the number of fish plates and this would lead to lesser maintenance cost, smoother running of trains and more comfort to the passangers.

So the long length of the rails is desired, however, the length is governed by the following factors.

(i) The length of the rails is so chosen that the manufacturing cost is most reasonable.

(ii) It depends upon the transportation facilities, so only those lengths of rails are possible which can be transported by longest wagons available on the railways.

(iii) To some extent, the length is also limited by the facilities of lifting and handling, during the loading and unloading of wagons.

On Indian Railways the standard lengths are;

Length = 12.80 m. (42 ft) for B.G (say 13m)

Length = 11.89 m. (39 ft) for M.G (say 12m)

Rail joints:

Rail joints are necessary to hold together the adjoining ends of the rails in the correct position, both in the horizontal and vertical planes. Rail joints ~~form~~ form the weakest part of the track. It is observed that strength of a rail joint is only 50 percent of the strength of a rail.

Requirements of an ideal joint:

An ideal or perfect rail joint is one which provides the same strength and stiffness as the other rail section of the track.

(i) The two rail ends should remain true in line both laterally and vertically when trains move on the track. This is necessary to avoid wheel jumping or changing its correct path of movements.

(ii) the rail joint should be as strong as stiff as the rail itself and should be elastic both laterally and horizontally.

(iii) the rail joint should be easily disconnectable so that it can be easily taken out without disturbing the whole track for the purposes of changing rail or a fish plate and lubricating the contact faces.

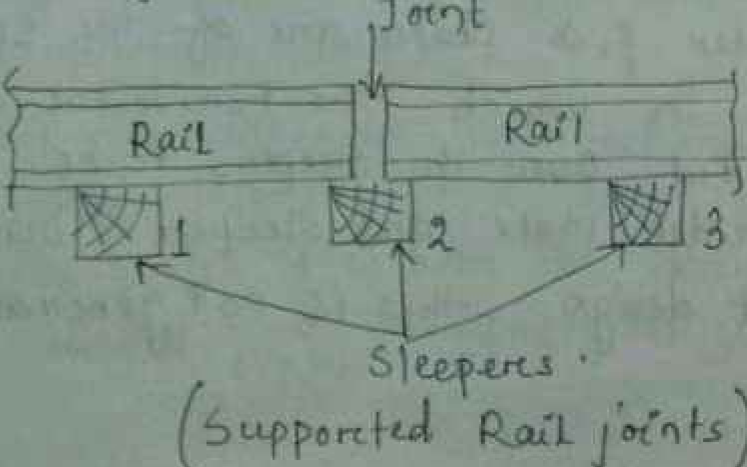
(iv) the rail joint should Provide enough space for free expansion and contraction to account for the effect of temperature variations.

(v) the joint should fulfill the above requirements with the minimum of initial and maintenance cost.

Types of Rail joints:

(i) Supported Rail joints:

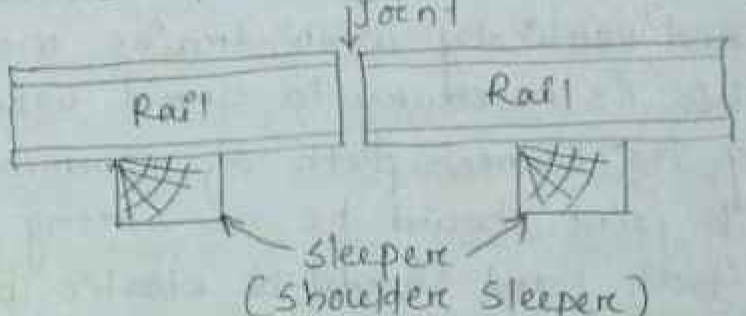
when the rail ends rest on a single sleeper called a "joint Sleeper" it is termed as Supported joint.



(Supported Rail joints)

(ii) Suspended Rail joint :

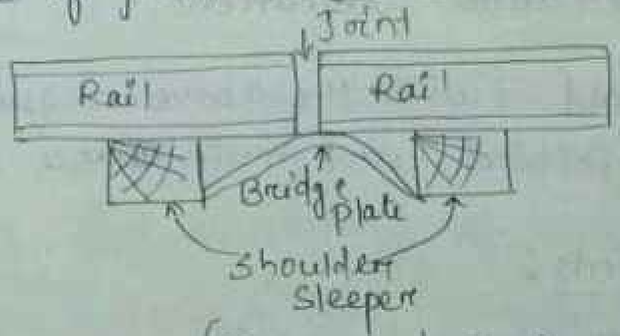
When rail ends are projected beyond sleepers called "shoulder sleeper" It is termed as suspended joint. This type of joint is generally used with timber and steel sleepers on Indian Railways.



(Suspended Rail joint)

(iii) Bridge joint :

When the rail ends are projected beyond sleepers as in case of suspended joint and they are connected by a flat or corrugated plate called "bridge plate", it is termed as a bridge joint. This type of joint is not used on Indian Railways.



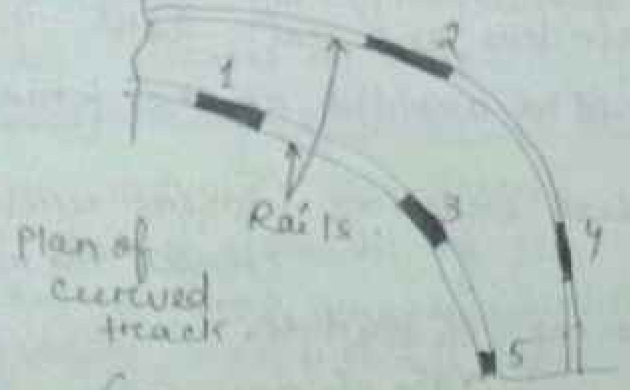
(Bridge joint)

(iv) Base joint :

This is similar to the bridge joint, with the difference that the inner fish plates are of bar type and outer fish plates are of the special angle type, in which the horizontal leg is further extended over the sleepers to be bolted to both bridge plate and sleeper. Due to complicated design, this is not generally used.

(v) Staggered or Broken joint:

In this type of joint, the joints of one track are not directly opposite to the joints of the other rail track. These joints are generally provided on curves, where the length of outer curved track is greater than the length of inner curved track.



(Staggered Rail joint.)

(vi) Square or Even joint:

In this also, the position of rail joint is the basis of its terminology, the joints of one rail track are directly opposite to the joints of other rail track. This type is generally used on straight track.

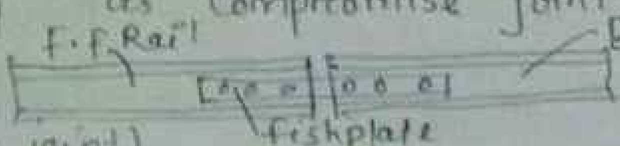
Plan of track

(Square or ~~of~~ Even Rail joint)

(vii) Composite joint: —

Compromise joint:

Where two different rail sections are required to be joined together, it is done by means of fishplates which fit both the rails and this is joint termed as compromise joint.



(Compromise joint)

(viii) Insulated joint:

When insulating medium is inserted in a rail joint to stop the flow of current beyond the track-circuited part, it is called insulated joint.

(ix) Expansion joint:

In bridges, provision for expansion and contraction is kept for girders and rails both. These types of joints should be avoided at the following places

(i) At rail level crossings (where railway track crosses the road).

(II) On approaches of bridges.

(III) On short bridge of any type.

(IV) On the ends or centre of span of long bridges

(x) Welded Rail joints:

The number of joints can be reduced by the process of welding of rails. Welded joints are considered as the most perfect and strongest type of joints.

Purpose of welding:

(i) To increase the length of the rail by joining two or more rails and thus to reduce the number of joints, and requirements of fish plates, which lead to economy and strength.

(ii) To repair the worn out or damaged rails and thus increase their life.

(iii) To build up worn out points and rails on the sharp curves.

(iv) To build up the burnt portion of rail head which is caused due to slippage of wheels over the rails or other defects or spots in rail steel.

Advantages of welding Rails:

(1) It satisfies the condition of a perfect joint and hence increases the life of the rail, as also the reduction in maintenance cost of track by about 20 to 40 percent.

(2) It reduces the creep due to increase in the length of rail and in turn friction as well.

(3) Expansion effect due to temperature is reduced which in turn also reduces the creep.

(4) Due to discontinuity of joints, a source of track weakness is reduced. The defects, such as hammering at rail joints, displacement of joint, disturbance in alignment and running surface, which result in bad riding quality, are eliminated.

(5) Long rail lengths being heavier, dampen the intensity of high frequency vibrations due to moving load.

(6) Welding increases the life of rails due to decrease in the wear of rails at joints.

(7) Welding facilitates track circuiting on electrified tracks.

(8) Welded rails provision on curves is under investigation. However, maximum curve length may be welded depending upon resistance and lateral displacement of track.

(9) Welded rails provides on large bridges for the span length are helpful as they result in better performance.

(10) the cost of track construction by welding of rails decreases due to less number of rail joints.

Creep

Definition

Creep is defined as the longitudinal movement of rails with respect to sleepers in a track. Rail have tendency to gradually move in the direction of dominant traffic. The Creep of rail is common to all railway tracks and its value varies from almost nothing in some cases to about 130mm per month in creep.

Indications of Creep:

Occurance of creep can be noticed from the following observations:

(i) Closing of successive expansion spaces at rails joints in the direction of creep & opening out of joints at the point from where the creep starts.

(ii) Marks on flanges and webs of rails made by spike heads by scraping or scratching as the rails slide.

Causes of Creep:

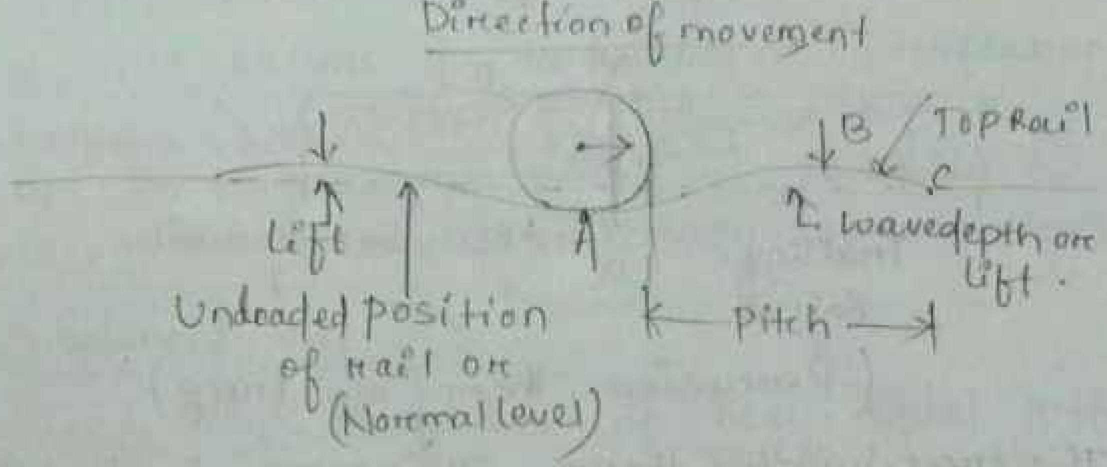
Various theories are present to explain the different causes of creep but non of them gives the true picture for real cause of creep in rails. Causes are:—

1. Wave Action or Wave theory:—

Wave motion is set up by moving of wheels. The vertical reverse curve is formed in the rails ahead of the wheels, resulting from the rail deflection under the load, is the chief cause of creep. The wheel push the wave with a tendency to force the rail in the direction of traffic. On a particular rail the joint action by Several wheels causes creep. As the wheel moves, the lift in front of the moving load is thus carried forward by the wheels and causes creep, where as the lift at the rear of wheel gets back to its normal position.

Direction of motion

(wave theory of creep)



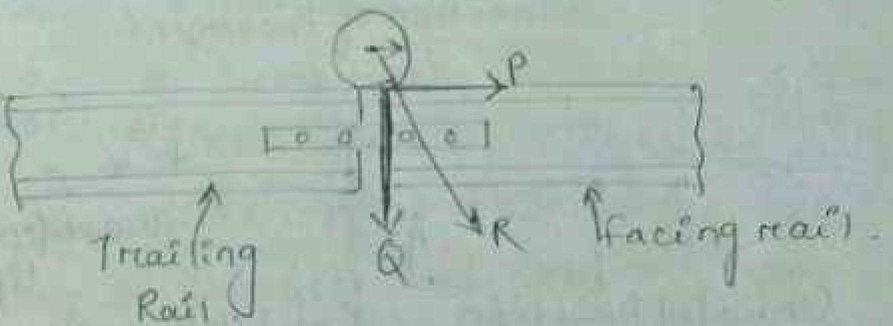
(formation of wave)
(wave-theory of creep)

* The pitch and depth of wave depends upon: —
  (i) Track modulus (Absolute value)
  (ii) Stiffness of track
  (iii) Stability of formation.

* The wave action can be reduced by adopting following measures.
  (i) Angular and heavy ballast - which develops good interlock,
  (ii) Increased stiffness of track.
  (iii) Lesser sleeper spacing.
  (iv) Bigger section of the rail.

2. Percussion Theory:—

This theory states that the creep is due to impact of wheel at the rail end ahead joints. The horizontal component tends to cause creep while the vertical component tends to bend down the rail end vertically. Hence ~~as~~ joint when the wheels leave the trailing rail and strike the facing rail end at each joint, it pushes the rail forward resulting in creep. ~~th~~ though the creep is very small in single impact but cumulative effect of number of wheels in quick succession results in sufficient creep.



(Percussion theory of Creep)

The creep by this theory will increase due to following factors:

(i) Due to weak & loose fish bolts.
(ii) Due to worn out fish plates. (Wear → worn)
(iii) Due to loose packing at joints
(iv) Due to wide expansion gap.
(v) Due to heavy axle loads moving at high Speed.

3. Drag or Dragging theory:

It states that backward thrust on driving wheels of the locomotive of train has got a tendency to push the rail off the track backward while the other wheels of the locomotive and the vehicles push the rail in the direction of travel. ~~as explained in~~ This results in creep of rails in the direction of movement of trains

4. Starting, Accelerating, Slowing down or Stopping of a train:-

When a train is starting or accelerating, the ~~backwar~~ backward thrust of the engine driving wheels tends to push the rails backward. When it is slowing down or coming to stop, the breaking effect tends to push the rails forward.

5. Expansion or Contraction of rails due to Temperature:—

Creep also occurs due to variation in temperature the creep in this case is influenced by the range in temperature variation, location of track, whether exposed or shady surroundings, etc

6. Unbalanced traffic:

(a) In a single line system if heavy equal traffic runs in both direction, the creep is almost balanced. Otherwise, heavy traffic in one direction will cause creep, which is partly balanced by light traffic ~~by~~ in opposite direction.

(b) In the double line system, trains on a particular line being unidirectional, creep occurs in both the lines.

→ There is some other factor also govern the magnitude & direction of creep.

(i) Alignment of track:—

Creep is observed greater on curves than on tangent railway track.

(ii) Grade of track:

Creep is more with steep gradient particularly if the trains move downward with heavy loads. though in the opposite direction, it is not impossible for creep to develop.

(iii) Types of Rails:

The old rails have more creep than new rails

(iv) ~~Direc~~ Direction of Heaviest traffic :-

If the loaded trains run in one direction and empty trains in opposite direction, creep will usually be found in the direction of loaded trains.

(v) Poor Maintenance of Track components & illdesign of super elevation, curves, joints, etc will also increase the creep.

It's observed that creep is not constant over any given time nor does it vary at uniform rate. nor does it continue in one direction, nor do both the rails creep by an equal amount. In fact, the direction and extent of creep cannot be predicted. Such variations may occur daily or may be seasonal.

* Effects of creep:

(i) Sleepers move out of square and out of position. this affects the gauge and alignment of track. As sleepers move, naturally the surface is also disturbed & finally results in an uncomfortable riding.

(ii) Rail-joints are opened out of their limit in some cases and stresses are set up in fish-plates and bolts due to which the bolts

Sometimes break. The rails are also battered at ends due to excessive gaps at joints. while at other places, joints are jammed and prevent required expansion due to temperature variation.

(iii) Point and crossings get distorted and it becomes very difficult to keep them to correct gauge and alignment. The movement of switches is made difficult and interlocking is thrown out of gear.

(iv) If any rail is removed from the track for any purpose, it becomes difficult to fix it again at proper position because by the time gap becomes too short or too long due to creep.

(v) Besides these effects, smashing of fish-plates and fish-bolts, bending of bars, kinks at joints of rails and forging of ballast ahead, are common effects of creep.

Prevention of Creep:

Prevention is always better than cure. If creep is not prevented in time, it will result in derailment. Following are the common methods adopted to prevent creep.

(1) Pulling back the rails:

If creep is distinctly visible, the remedy is to pull back the rails to their original position. For doing this, first inspect the track, note the extent of pulling back distance and determine the point from which to begin. Now start pulling the rails back to their original positions by means of crow bars and hooks provided through the fish bolt holes of rail. In pulling back, the positions of joints relative to

Sleepers must be maintained. and both the rail joints must be in their relative positions.

2. Provision of Anchors or Anticreepers:—

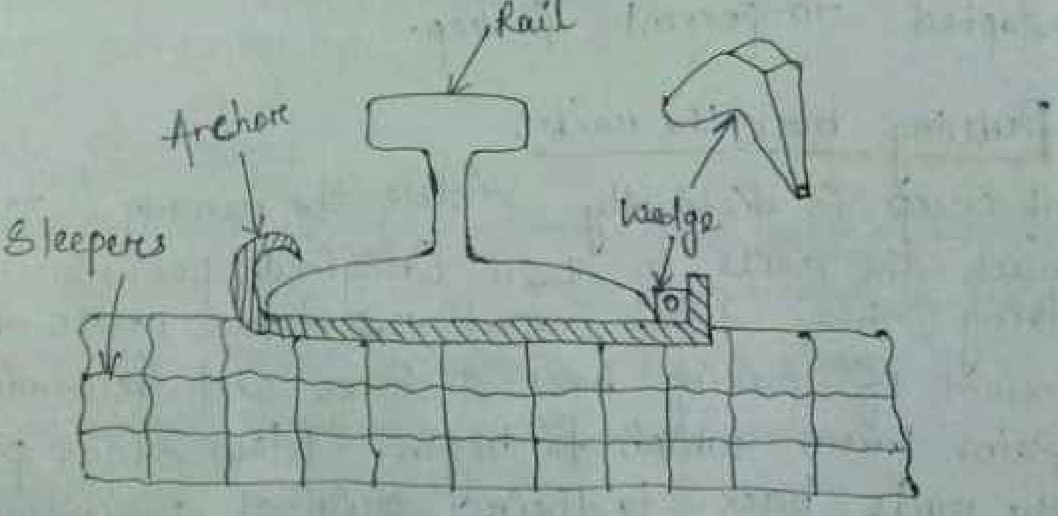
The creep of the track can be prevented by use of Anchors and sufficient Crib ballast. For creep of 7.5 cm to 15 cm, in a month 4-anchors per rail and for creep of 22.5 cm to 25 cm, 6-anchores per rail are used in the Indian practice.

Anchors are fastened to the foot of rail and kept in perfect contact with the side of the sleeper being the side opposite to the direction of creep. If creep occurs in both directions, anticreepers are provided on both the sides of sleepers, starting from the centre of the rail and should never be fixed near the joints

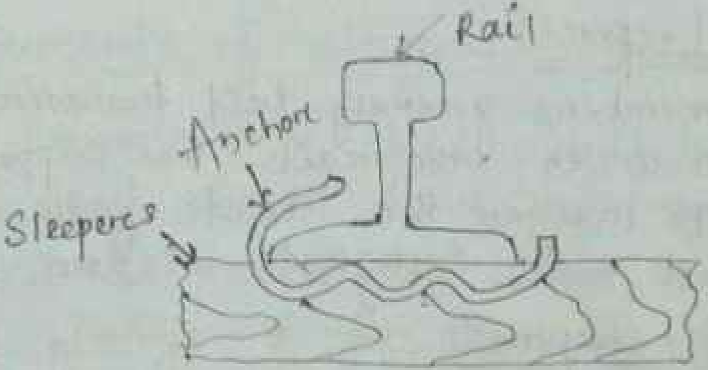
Anchors are fixed to rails either (i) by wedging action.

(ii) by clamping

(iii) by a spring grip



Anchor placed by wedging Action



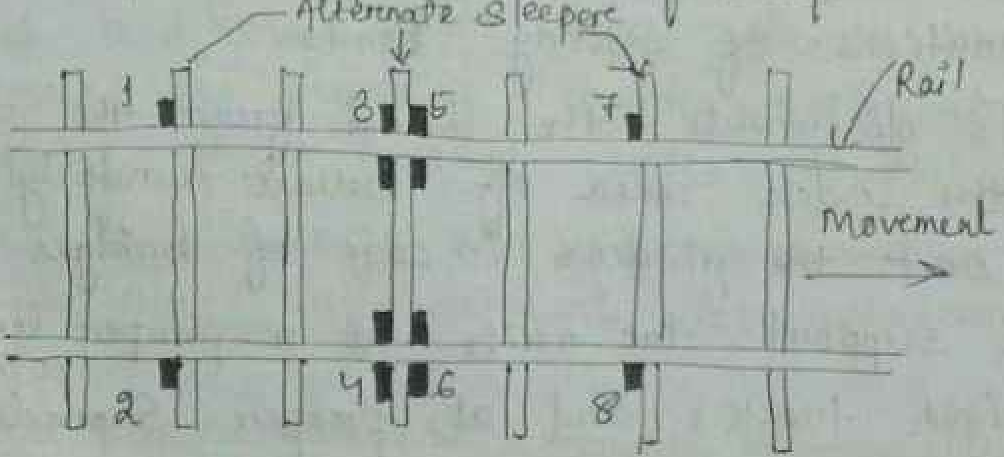
Anchor placed by a spring Grip

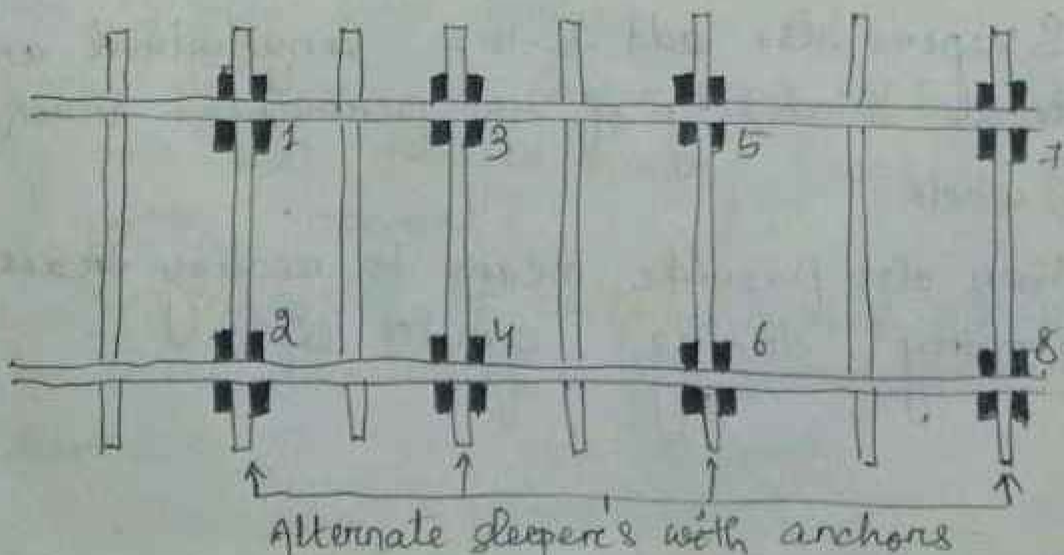
3. Use of Steel of sleeper :-

→ Sleeper should be of such a type and with such fittings that they effectively prevent the rail from creeping on them.

→ The sleeper must have a good grip with the ballast to resist the movement of the sleepers in the ballast. Steel sleepers are the best for this purpose.

→ Increase in the number of sleepers will, therefore also help in the prevention of creep.





Alternate sleeper's with anchors

Definition **Sleepers:**

Sleepers are members generally laid transverse to the rails on which the rails are supported and fixed, to transfer the loads from rails to the ballast and subgrade below.

Functions of Sleepers:

Sleepers perform the following functions:

(i) To hold the rails to correct gauge. (exact straight and flat curves, loose in sharp curves and tight in diamond crossings.

(ii) To hold the rails in proper level or transverse tilt i.e, level in turnouts, cross-overs, etc, and at 1 in 20 tilt in straight tracks, so as to provide a firm and even support to rails.

(iii) To act an elastic medium in between the ballast and rails to absorb the blows and vibrations of moving loads.

(iv) To distribute the load from the rails to the index area of ballast underlying it or to the girders in case of bridges.

(v) To support the rails at a proper level in straight tracks and at proper superelevation on curves.

(vi) Sleepers also add to the longitudinal and lateral stability of the permanent track on the whole.

(vii) they also provide means to rectify track geometry during service life.

Requirements of sleepers:

(i) The sleepers to be used should be economical. i.e., they should have minimum possible initial & maintenance costs.

(ii) The fittings of the sleepers should be such that they can be easily adjusted during maintenance operations such as easy lifting, packing, removal and replacement.

(iii) The weight of sleepers should not be too heavy or excessively light, i.e, they should have moderate weight, for ease of handling.

(iv) The design of sleepers should be such that the gauge, alignment of track and levels of the rails can be easily adjusted and maintained.

(v) The bearing area of sleepers below the rail seat and over the ballast should be enough to resist the crushing due to rail seat and crushing of the ballast underneath the sleeper.

(vi) The sleeper design and spacing should be such as to facilitate easy removal and replacement of ballast.

(vii) The sleepers should be capable of resisting shocks and vibrations due to passage of heavy loads of high speed trains.

(viii) The design of the sleepers should be such that they are not damaged during packing ~~process~~ ~~pro~~ processes.

(ix) The insulation of rails should be possible for track circuiting, if required, through sleepers.

(x) The design of sleepers should be such that they are not pushed out easily due to moving trains especially with steel sleepers with rounded ends.

Classification of sleepers:

Sleeper can be classified according to the materials used in their construction, in the following catagories:

1. Wooden sleepers
2. Metal sleepers
   a. Cast iron sleeper
   b. steel sleepers
3. Concrete sleepers
   a. Reinforced concrete sleepers
   b. prestressed concrete sleepers.

Timber or Wooden sleepers:

Wooden sleepers are regarded to be best as they fulfill almost all the requirements of an ideal sleepers. the life of sleepers depends upon their ability to resist wear, Decay, Attack by vermin, white ant and Quality of the timber used.

Advantages:

(21.67% forest)

(i) Timber is easily available in all parts of India.

(ii) Fittings for wooden sleepers are few and simple in design.

(iii) These sleepers are able to resist the shocks and vibrations due to heavy moving loads and also give less noisy track.

(iv) wooden sleepers are easy to lay, relay, pack, lift and maintain.

(v) These wooden sleepers are suitable for all types of ballast.

(vi) They are best for track circuited operations and moreover, wooden sleepers are over-all economical.

Disadvantages:—

(i) The sleepers are subjected to wear, decay, attack by white ants, spike killing, warping, cracking, end splitting, rail cutting etc.

(ii) It is difficult to maintain the gauge in case of wooden sleepers.

(iii) Track is easily disturbed, i.e. alignment maintenance is difficult.

(iv) Wooden sleepers have got minimum service life (12 to 15 years) as compared to other types of sleepers.

(v) Maintenance cost of wooden sleepers is highest as compared to other sleepers.

Standard dimensions of wooden sleepers:

Gauge	Length (cm)	width (cm)	Depth (cm) ~~Sleeper~~	Bearing Area per (sq.m) Sleeper
BG	275	25	12.5	0.465
MG	180	20	11.5	0.31
NG	150	18	11.5	0.209.

Metal Sleepers:

Due to the growing scarcity of wooden sleepers, their high cost & short life metal sleepers are now being widely adopted in India.

Metal sleepers are either of steel or cast iron. Cast iron is in greater use than steel for sleeper because it is less prone to corrosion.

Metal sleepers should satisfy the following requirements.

(i) they should bear the tensile and compressive stresses which come on to them.

(ii) They should provide sufficient area for rails

(iii) Tamping and packing of ballast should not disturb the sleeper.

(iv) for track circuiting, insulation* should be possible.

(v) metal sleeper should be overall economical as compared to wooden sleepers.

Advantages:

(i) Metal sleepers are uniform in strength and durability.

(ii) In metal sleepers, the performance of fittings is better and hence lesser creep occurs

(iii) Metal sleepers are economical, as life is longer and maintenance is easier.

(iv) Gauge can be easily adjusted & maintained in case of metal sleepers.

(v) For Metal sleepers, frequent renewal is not required.

Disadvantages:

(i) More ballast is required than other type of sleepers.

(ii) fittings required are greater in number, and difficult to maintain and inspection.

(iii) Metals, C.I. or steel, are liable to rusting / corrosion.

(iv) Metal being good conductor of ~~elastricity~~ electricity interferes with track circuiting.

(v) Metal sleepers are not suitable for bridges, level crossings and in case of points and crossings.

Concrete Sleepers:

These sleepers ~~were~~ is ~~ended~~ used due to chronic shortage of good wooden sleepers and need for better design and economy of sleepers on sustainable basis.

These sleepers are mainly two types:

(a) Reinforced Concrete sleepers.

(b) prestressed Concrete sleepers.

Advantages:

(i) these sleepers are free from natural decay and attacks by vermin, insects, etc

(ii) they have maximum life when compared to other sleepers, the life under normal conditions is 40 to 60 years.

(iii) this is not affected by moisture, chemical action of ballast and sub-soil salt.

(iv) there is no difficulty in the track circuiting, required for electrifying the track.

(v) the high weight of sleepers helps in minimising joint maintenance by providing longer welded length, greater stability of the track & better resistance against temperature variations

Disadvantages

(i) The weight of concrete sleeper is as high as 2.5 to 3 times of wooden sleeper, requiring the mechanical appliances for handling.

(ii) These sleepers require pads and plugs for spikes

(iii) They damage the bottom edge during the packing.

(iv) The scrap value is almost nil.
* - value of dismantled material
[illegible]

(v) The damaged to the concrete sleeper is very heavy in case of derailment

Comparison of Different types of Sleepers:—

Point of comparision	Wooden sleeper	C.I. Sleeper	Steel sleeper	Concrete sleeper
1. Cost per sleeper	Low	medium	High	Depends upon design.
2. Life	10 to 15 yrs for untreated 20 to 25 for treated	35 to 50 years	35 to 50 years	40 to 60 years.
3. Weight per sleeper for B.G track	Low	Heavy	medium	Depends upon design but heavier than others.
4. Maintenance cost	Higher than other sleepers	minimum	moderate	moderate
5. Overall economy	Cheaper in the initial cost but expensive in long run.	Costlier in first cost but cheaper in long run.	Same as for C.I.	Undertreat

Point of comparison	Wooden sleeper	C I sleeper	Steel sleeper	Concrete sleeper
6. Handling	Not liable to break under rough handling.	Liable to break under rough handling	Not liable to break, if clip & bolts are used	With improved design not liable to break
7. Track fittings.	Requires less fittings	Requires more fittings.	Requires less fittings	Requires less fittings
8. Elasticity	Good	Not so good	Not So good	Not good.
9. Laying & Relaying	Easiest	Difficult due to large number of fittings	easy due to light weight,	Difficult by manual labour. easy if mechanical devices are used.
10. Rigidity of track	poor both laterally and longitudinally	Better than timber sleepers.	Better than timber Sleepers	Best because of heavy dead weight.
11. Suitability of track	Generally suitable in all Locations except areas of vermins & whiteants Specially suitable for points & no stings, bridges, station yards & level crossings.	suitable only for stone ballast. Unsuitable in station yards.	Suitable only for stone ballast. Unsuitable for station yards & Coastal areas.	Suitable for any Location on railway track.
12. Track Circuiting	Best	Restricted. Insulating pads are necessary.	Restricted insulating pads are necessary	Moderate

Point of Comparision	Wooden sleeper	C.I. sleeper	Steel sleeper	Concrete sleeper
13. Scrap value	very little	Highest	Next to C.I	NIL
14. Gauge	Doesnot maintain proper gauge	slight play in gauge due to play in the bar and socket.	maintains proper gauge	Depends upon design, Improved design maintains proper gauge
15. Renewal	Easy	Difficult	Difficult.	Difficult.
16. Gauge Adjustment	Difficult	Easy	Easy	Easy
17. Creep of Rails	Heavy. Anchores are necessary in large numbers	fittings function as creep anchores. Requires constant attention in C.S.T.-9 sleepers.	No difficulty in clips & bolt type	No Anchor is necessary.

Ballast

Definition

(i) Ballast is the granular material usually broken stone or brick, Kankar, gravel or sand placed and packed below and around the sleepers to transmit load from sleepers to formation and at the same time allowing drainage of the track.

(ii) It provides a suitable foundation for the sleepers and also hold the sleepers in their correct level and position.

(iii) The lateral stability of a track depends on the ballast.

Functions of Ballast:—

(i) It transfers the load from the sleeper to the subgrade and then distributes it uniformly over a larger area of the formation.

(ii) It holds the sleepers in position and prevents the lateral and longitudinal movement, due to dynamic loads and vibrations of moving trains.

(iii) It imparts some degree of elasticity to the track.

(iv) It provides easy means of maintaining the correct levels of the two lines of a track and for correcting track alignment.

(v) It provides good drained foundation immediately below the sleepers and helps to protect the top surface of the formation.

Requirements of the Good ballast:

(i) It should be able to withstand hand-packing without disintegrating.

(ii) It should not ~~not~~ make the track dusty or muddy due to powder under dynamic wheel loads but should be capable of being cleaned to provide good drainage.

~~(iii) It should be able to withstand hand-packing~~

(iii) It should allow for easy drainage with minimum soakage and the voids should be large enough to prevent capillary action.

(iv) It should offer resistance to abrasion and weathering.

* Abrasion - Wear due to rubbing action of particles with each other.
* Weathering - Cracking of material due to variation in temperature, moisture & freezing

(V) It should retain its position laterally & longitudinally under all conditions of traffic, particularly on curves, where it should be able to prevent transverse displacement of sleepers.

(vi) It should not produce any chemical action with rail and metal sleepers.

(vii) The size of stone ballast should be 5 cm for wooden sleepers, 4 cm for metal sleepers and 2.5 cm for turnouts and crossovers.

(viii) The materials should be easily workable by means of the implements in use.

(ix) The ballast should be available in nearby quarries so that it reduces the cost of supply. It should also fulfil the requirements of quality, amount of traffic, life and maintenance cost.

(x) In short, the ballast should be such which fulfils the characteristics of strength, cleanability, durability, drainability, economy & stability & is workable with specific size with no harmful effects on rails & sleepers.

Types of Ballast :

The different materials used as ballast in India are broken stone, gravel, sand, ashes or cinders, Soft aggregates like moorum, Kankar, Overburnt and broken brickbats, blast furnace slag and sometimes selected earth.

Sl no. Ballast materials	Merits	Demerits	Suitability of various materials
1. Broken stones [A] Igneous Rocks	• Such as Granite, Basalt, Quartzite, Trap, etc. have all the characteristics such as strength, stability, durability, drainability, economy and workability which are required for a good ballast. • Ballast cushion is minimum.	• Initial cost is high • Angular shape injures wooden sleepers during packing.	• Best suited for ballast.
[B] Aqueous Rocks	• Such as lime stones and sand stones. These fulfil almost all the good qualities of ballast. • It is less costly than igneous rocks.	• Easily broken down to pieces.	• Fairly good ballast.
2. Gravel	• Less costly as no breaking cost. • It does not injure wooden	• Packing gets easily disturbed in flat sleepers. • Greater cushion is necessary	• Suitable ballast material where good ballast material is not available

	Sleepers. Maintains good packing on p. • It has best drainage quality.	• Requires ballast wall to prevent spreading.	
3. Brick	• It is cheap. • Readily & locally available. • It has fairly good drainage facilities.	• Unsuitable for heavy and high speed traffic. • Makes the tracks dusty & muddy. Corrodes metal sleepers & rails. • Causes roaring* of rails.	• Good ballast material, where suitable ballast material is not available.
4. Moorum	• Best for sidings & main tracks when nearly formed, particularly in Black Cotton Soil to form a sub ballast. • Cheapest if locally available. • Makes the track less noisy. • Suitable for station yards. • It possesses good drainage properties.	• Moorum is very soft & turns into dust in very short time. • Maintenance of track with moorum as ballast is very difficult.	• Never used as ballast.

S.no.	Ballast material	Merits	Demerits	Suitability of various material
5.	Ashes or Cinders	• Excellent for station yards. • prevents vegetable growth. • It possesses fairly good drainage properties. • Easy handling & less material cost. • Useful in emergency as available in large quantities in short time for repairing formation and packing of tracks.	• Corrodes metal sleeper & foot of the rails. • Soft and light, so the track becomes dusty. • Dusty track is objectionable especially in dry weather.	• Good ballast for station yards. • Specially usefull in emergency.
6.	Sand	• It is cheap material. • Good drainage provided if free from vegetation and earth. • Produces a silent track. • It is	• Sand is easily blown off and causes heavy wear on rails and moving parts of train. • Sand ballast requires frequent renewal. • Maintenance of ballast track is difficult.	• Unsuitable for heavy and high speed tracks but can be used for M.G. and N.G. with light traffic.

Fixture for Broad gauge

Rail joints – fish plates – fish bolts – fang bolts – Hook bolts – Rail chairs and keys – Bearing plates – Blocks – Spikes – Elastic fastening – Anchors & Anti creepers.

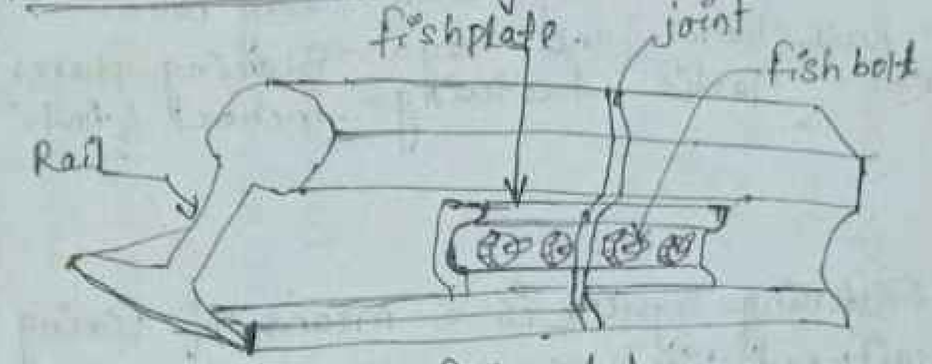
fastening:

A rail fastening system is a means of fixing rails to railroad ties. The terms rail anchors, tie plates, chairs and track fasteners are used to refer to parts or all of a rail fastening system. Various types of fastening have been used over years.

Fish plate:

In rail terminology, a fishplate, joint bar is a metal bar that is bolted to the ends of two rails to join them together in a track.
the name is derived from fish, a wooden bar with a curved profile used to strengthen a ship's mast. The top and bottom edges are tapered inwards so the device wedges itself between the top & bottom of the rail when it is bolted into place.
In the rail transport modelling, a fishplate is often a small copper or nickel silver plate that slips on to both rails to provide the functions of maintaining alignment and electrical continuity.

Rail to Rail fastenings:

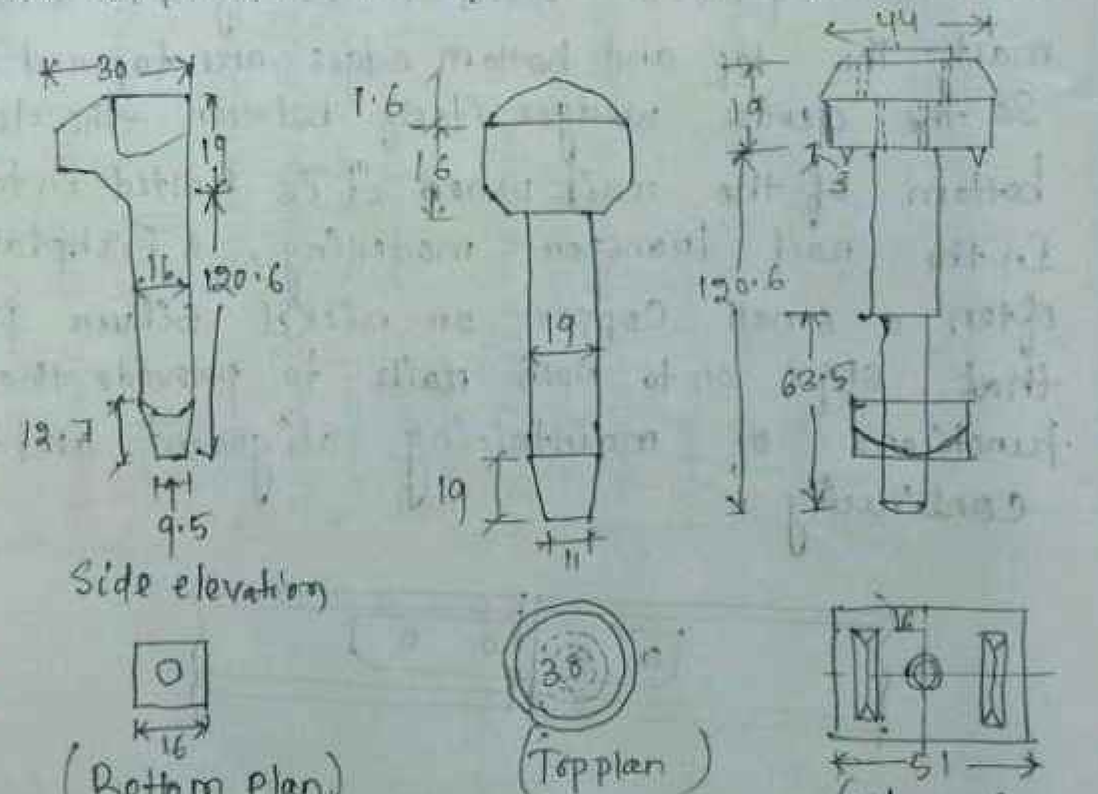


fish plate.

Connection of rails to sleeper:

the railroad spike connects rail and railway sleeper to be a unit. Railroad spike increase the rigidity of track panel.

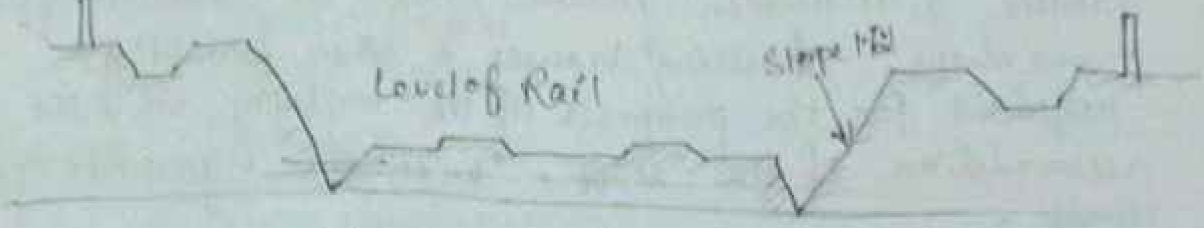
the common railroad spikes include two types - dog spike and screw spike. The dog spike consists of a duck bill head and a square shank, and its nail point is wedge-shaped.



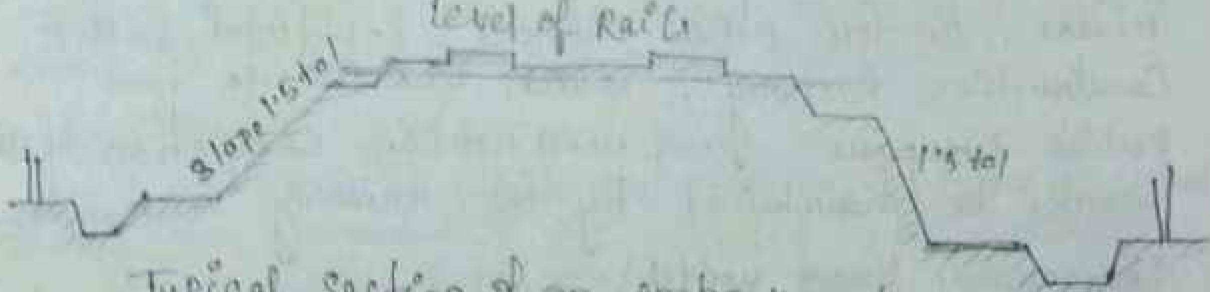
(Dog spike) (Round spike) (Flang bolt)

Chapter-4

Geometric for Broad gauge:



Typical section of Railway in cutting.



Typical section of an embankment

Permanent land width:—

(I) It is land which will be required permanently after the railway is open for traffic and the work of construction is complete.

(II) Under this head will be included all land to be occupied by the formation of the permanent line of railway with side slopes of banks and cutting, and the berms connected therewith; catch water drains and borrow pits or such parts of them as it is necessary to retain; the entrance to tunnels & shaft belonging to them; the sites of bridges, & protection or training works; station yard; landing places for railway ferries; ground to be occupied by works belonging to the railway such as gas works & arrangements for water supply. Septic tank, collecting pits, filter beds and pump installations, etc.

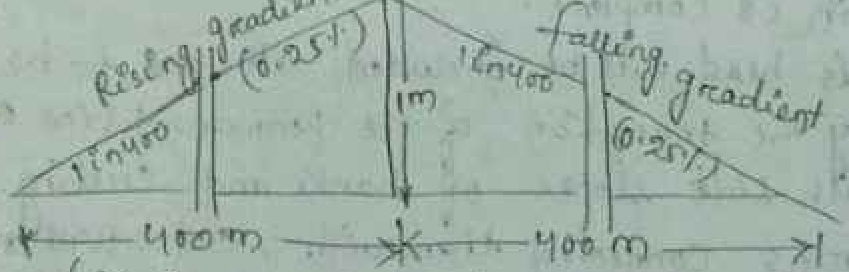
Ground for the storage manufacture or acquisition of material; land for Sanitary zones, plantations; gardens, & recreation grounds, sites for stations offices workshops; dwelling houses & other buildings required for the purposes of the railway, or the accomodation of the staff, with the grounds, yards roads.

(iii) Under this head will also be included land outside the permanent railway boundary, which will be required for the permanent diversion of roads or rivers, or for other works incidental to the Construction Railway, which are made for public purposes and will not on completion of the works be maintained by the railway authorities.

Temporary land width:—

It is the land which is acquired for temporary purposes only, & which is disposed of after the work of construction is completed.

Gradient for drainage:—



(rising and falling gradient)

(i) Drainage is defined as interception, collection & disposal of water away from track. Drainage is the most important factor in track maintenance & for stability of cuttings.

(ii) when water seeps into the formation, it weakens the bonds between the soil particles, softens the soil & results in creation of ballast pockets - which this is very harmful, hence quick disposal of water from formation is very essential.

(iii) Conventional Drainage Systems: —

- Surface drainage
- Side Drains
- Catch water Drains
- Sub surface drains.

Super elevation:

(1) Cant or Super elevation: —

It's amount by which one rail is raised above the other rail. It is positive when the outer rail on a curved track is raised above inner rail and is negative when the inner rail on a curved track is raised is above the outer rail.

(2) Equilibrium Speed: —

It is the Speed at which the centrifugal force developed during the movement of the vehicle on a curved track is exactly balanced by the cant provided.

(3) Cant deficiency: —

Cant deficiency occurs when a train travels around a curve at a speed higher than the equilibrium speed. It is the difference between the theoritical cant required for such higher speed and actual cant provided.

(4) Cant excess: —

Cant excess occurs when a train travels around a curve at a speed lower than the equilibrium speed. It is the difference between the actual cant & the theoritical cant required for such a lower speed.

(5) Maximum Permissible Speed of the curve: —

It is the highest speed which may be permitted one curve taking into consideration the radius of the curvature, actual cant, cant deficiency, cant excess & the length of transition. When the maximum permissible speed on a curve is less than the maximum sectional speed of the section of a line, permanent speed restriction becomes necessary

6. Cant gradient:-

Cant gradient and cant deficiency gradient indicate the amount by which cant or deficiency of cant is increased or reduced in a given length of transition. Ex- 1 in 1000 Means that cant or deficiency of cant of 1mm is gained or lost in every 1000mm of transition length.

7. Rate of change of cant:— (35mm)

It is the rate at which cant or cant deficiency is increased or reduced per second, at the maximum permissible speed of the vehicle passing over the transition curve.

8. Transition Curve:-

It is defined as the curve, in which the change of radius is progressive throughout its length and is usually provided in a shape of a cubic parabola at each end of the circular curve. It affords a gradual increase of ~~superelevation~~ Curvature from zero at the tangent point to the specified radius of circular and permits a gradual increase of super elevation so that the full superelevation is attained simultaneously with the curvature of the circular arc.

Superelevation:-

The equilibrium superelevation or cant ~~necessary~~ for any speed is calculated from the formula.

$$\boxed{C = \frac{GV^2}{127R}}$$

C = superelevation or cant in mm.

G = Gauge of track + width of rail head in mm.

R = Radius of the curve in meters.

Necessity of Superelevation:—

In order to counteract the effect of centrifugal force the outside rail of the curve may be elevated above the inside rail effectively moving the centre of gravity of the rolling stock laterally towards the inside rail. This procedure generally referred to as Super elevation.

Limitation of Super elevation:—

Gauge	Group	Limiting value of cant (mm) under normal conditions	Limiting value of cant (mm) with special permission of civil Engineer
BG	A	165	185
BG	B and C	165.	—
BG	D and E	140	—
MG	—	90	100
NG	—	65	75.

Chapter-05

Points And Crossing:

Definition:

The arrangement which is used to transfer the train from one track to another is known as points and crossings.

Necessity:

(i) point and crossing are provided to help transfer railway vehicle from one track to another.

(ii) the track may be parallel to diverging from or converging with each other. point and crossing are necessary because the wheels of railway vehicles are provided with inside flange and therefore they require this in special arrangement in order to navigate their way on the rail.

(iii) the points or switches aid in diverting the vehicles and the crossing provide gaps in the rails so as to help the flanged wheels to roll over them.

(iv) A complete set of points and crossing, along with lead rails, is called turnout.

Points or Switches:

A pair of tongue rail and stock rail with necessary connection and fitting forms a switch

Crossing: — It is the device introduced at the ~~joint~~ junction where two rails cross each other to permit the wheel flanges of a railway vehicle to pass from one track to another.

Switches: —

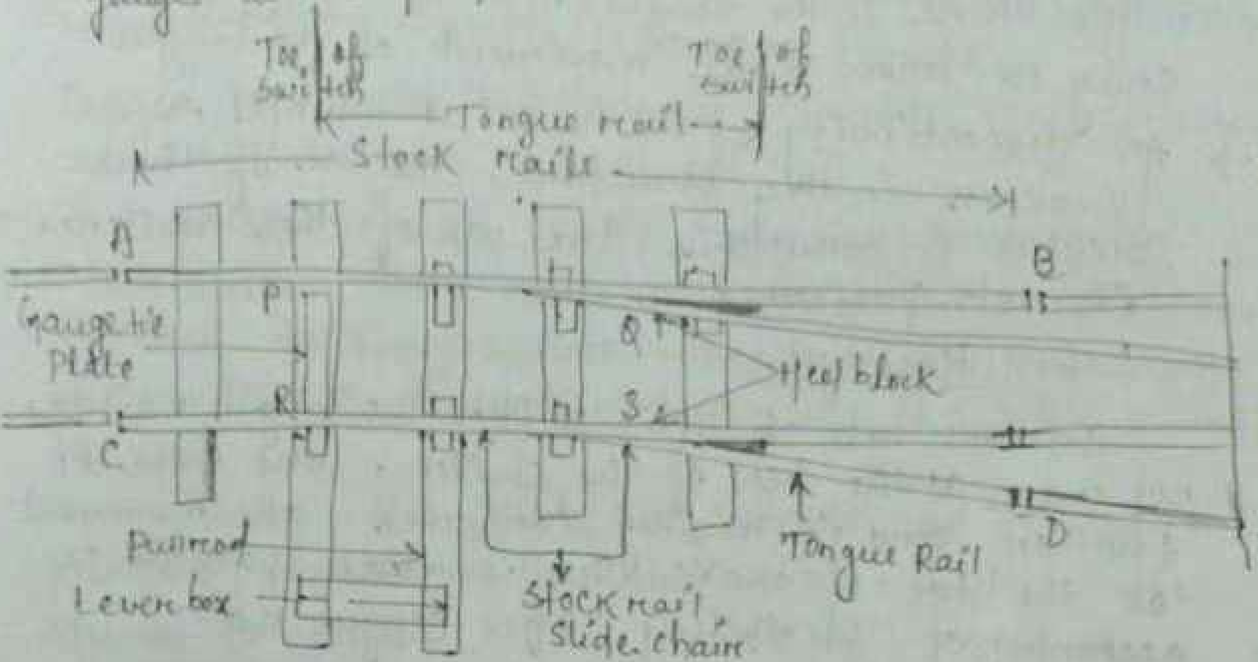
→ A pair of stock rail, AB and CD made of medium manganese steel.

→ A pair of tongue rails, PQ & RS also known as switch rails made withstand wear. The tongue rails are machined to very thin section to obtain a snug fit with the stock rail is called 'toe' and thicker end is called the 'heel'.

→ A no. of slide chairs to support the tongue rail and enable its movement towards or away from the stock rail.

→ Two or more stretcher bars connecting both the tongue rails close to the toe for the purpose of holding them at a fixed distance from each other.

→ A gauge ties plate to fix gauges and ensure correct gauge at the point.



Types of switches :—

Switches are of two types, namely 'stud switches' and 'split switch'.

In 'stud switch' no separate tongue rail is provided and some portion of the track is moved from one side to the other side

In 'split switch' a pair of stock rail and a pair of tongue rails are present.

* Split switches are two types :—

1) Loose Heel type :—

→ In this type of split switch, the switch or tongue rail finishes at the heel of the switch to enable movement of the free end of the tongue rail

→ the fish plates holding the tongue rail may be straight or highly bent

→ the tongue rail is fastened to the stock rail with the help of a fishing fit block and four bolts.

→ All the fish bolts in the lead rail are tightened while those in the tongue rail are kept loose or snug to allow free movement of the tongue

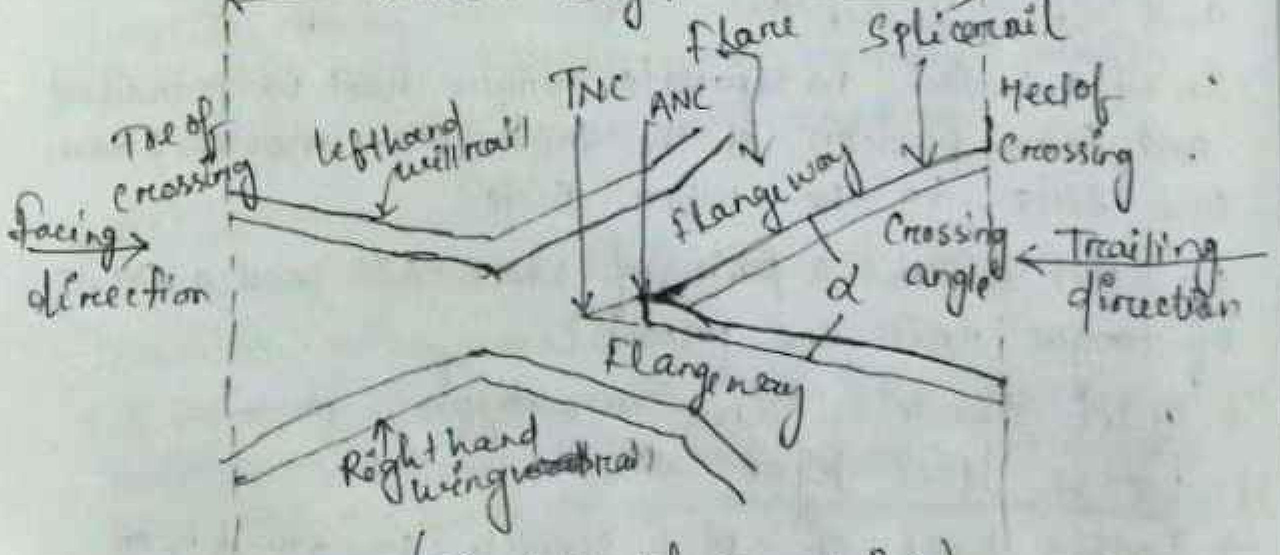
→ As discontinuity of the track at the heel is a weakness in the structure, the use of these switches in structures, the use of these switches is not preferred.

(2) fixed Heel type:—

In this type of split switch the tongue rail does not endie at the heel of the switch. but extends further and is rigidly connected. the movement at the toe of the switch is made possible on account of flexibility of tongue rail.

Crossing:—

A crossing device introduced at the point/Junction where two gauge faces/rail cross each other to permit the wheel flanges of a railway vehicle to pass from one track to each other.



(Details of Crossing)

TNC = theoritical Nose of crossing.
ANC = Actual nose of crossing.

Flare : signal used for warning the driver of an approaching train of any obstruction.

Flangeway = Passageway for the flange of a wheel running on rails.

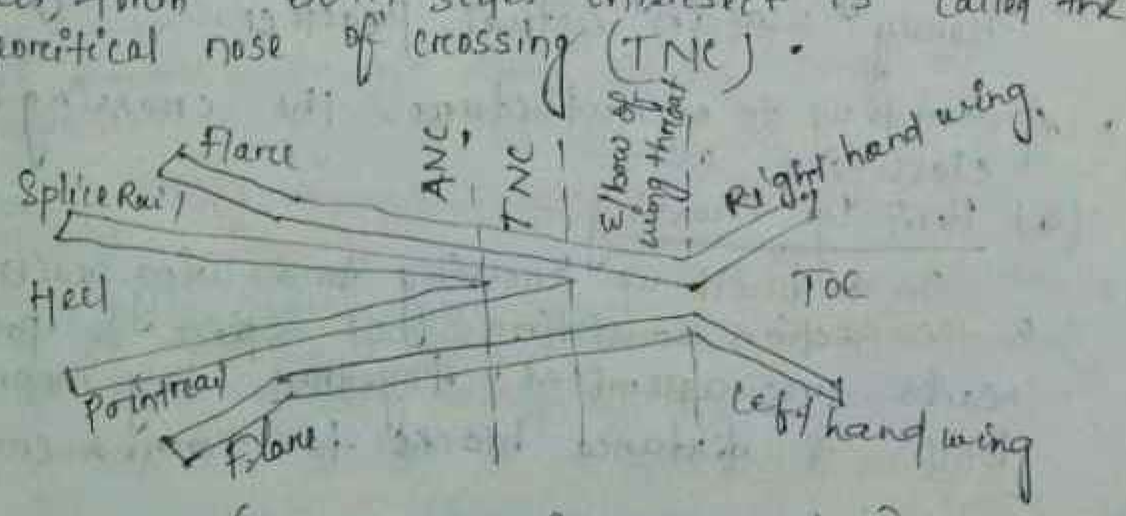
wing rail = The bentup length of rail in front of nose of crossing which helps in channelising train ~~which helps~~ wheels in proper route.

Tongue rail = It is a tapered moveable rail connected at its thick end to lead rail.

- A crossing consists of the following Components.

(i) Two rails, point rails and splice rails, which are machined to form a nose. the point rail ends at the nose whereas the splice rail joins it a little behind the nose.

Theoritically, the point rail should end in a point and be made as thin as possible, but a knife edge of point rail would break off under the movement of traffic. The point rail therefore, has its fine end slightly cut off to form a blunt nose, with a thickness of 6mm. the toe of the blunt nose is called the (actual nose of crossing) (ANC) and the theoritical point where the gauge faces form both sides intersect is called the theoritical nose of crossing (TNC).



(Point Rail & Splice Rail)

(ii) Two wing rails consisting of a right hand and a left hand wing rail that converge to from a throat and diverge again on either side of the nose. Wing rails are flared at the ends to facilitate the entry and exit of the flanged wheel in the gap.

(iii) A pair of check rails to guide the wheel flanges preventing them from moving sideway which would otherwise may result in the wheel hitting the nose of the crossing as it moves in the facing direction.

- Types of crossing :- ∠(less than 90°)

(a) 'V' crossing / (AD) Acute angle crossing) :-

~~It is~~. It is the type of crossing in which the intersection of two gauge faces forms on acute angle. Ex - when a right rail crosses a left rail it make an acute crossing. So unlike rail crossing from an acute crossing.

(b) Diamond crossing :- In which the two gauge faces meet an an obtuse angle ∠(more than 90°) when right on left rail crosses a similar rail, it makes an obtuse crossing.

(c) A Square crossing :- In which two tracks crossing at right angles, such crossings are rarely used in actual practice.

- According to manufacture, the crossing may be classified as :-

(a) Built up Crossing :-

In a built-up crossing two wing rails and a V-section consisting of splice & point rails are assembled together by means of bolts & distance blocks to form a crossing

Advantages:—

(a) Initial cost is low.

(b) Repair can be carried out by welding

(b) cast steel crossing:—

This is one piece crossing with no bolts and there force requiring very little maintenance comparatively.

Advantages:—

→ Longer life.

Disadvantages:—

→ Initial cost is high.

→ Repair & maintenance causes a no of problem.

(c) Combined rail and cast crossing:—

It is a combination of a built up & cast steel crossing and consists of a cast steel nose finished to ordinary rail faces to form the two legs of the crossing.

• (Cast manganese steel) CMS crossing:—

It possess higher strength, offer more resistance to wear & consequently have a longer life.

Advantages:—

→ Less wear & tear.

→ Longer life

→ Free from bolts as wheel as other component that normally to get ~~losse~~ Loose as a result of movement of traffic.

Spring and movable crossing:—

This type of crossing is useful when there is high-speed traffic on the main track and slow-speed traffic on the turnout track.

—x—

Chapter-6

Methods of Laying & Maintenance of Track:—

Essential of track maintenance:—

1. The gauge should be correct or within the Specified limits.
2. There should be no difference in cross leveli ~~expect~~ on except on curves, where cross levels vary in order to provide super elevation
3. Longitudinal levels should be uniform.
4. The alignment should be straight and kink-free.
5. The ballast should be adequate and sleeper should be well packed.
6. The track drainage should be good and formation should be well trained.

• Railway track can be maintained either conventionally by manual labor or by the application of modern methods of track ~~maintenance~~ maintenance:—

(1) Through packing
(2) Systematic Over hauling
(3) Packing up slacks.

1. Through packing:—

→ Opening of Road:—

The ballast is dug out on either side of the rail seat for a depth of 50mm (2") below the bottom of the sleeper with the help of a shovel with a wire claw. On the out side, the width of the opening should extend up to the end of the sleeper. On the inside it should extend from the rail seat to a distance of 450mm (18") in case of BG, 350mm (14") in case of MG, & 250mm (10") in case of NG.

→ Examination of Rails, sleepers and fastening :—

The rails, sleepers and fastening to be used are thoroughly examined. Defective sleepers are removed and loose fastening are tightened. Any kinks in rails are removed.

→ Squaring of Sleepers :—

To do this one of the rails is taken as the sighting rail and the correct sleeper spacing is marked on it.

The position of the square of sleeper is checked with reference to the second rail with the help of a T - square

The sleeper attended to after this defects have been established, which may include their being out of square or at incorrect spacing

→ Aligning the track :—

a. The alignment of the track is normally checked visually, where in the rail is visually assessed ~~from~~ form a distance of about four rail lengths or so.

b. Small errors in the ~~management~~ alignment are connected by slewing the track after loosening the cores at the ends and drawing out sufficient ballast at the ends of the sleeper.

c. Slewing is carried out by planting crowbar deep into the ballast at an angle not more than 30 from the vertical.

• Advantages of track maintenance :—

1. If the track is suitably maintained, the life of the track as well as that of the rolling stock increases since there is lesser wear and tear of their components.

2. Regular track maintenance helps in reducing operating costs and fuel consumption.
3. Small maintenance jobs done at the appropriate time, such as tightening a bolt or key, hammering the dog spike. etc help in avoiding loss of concerned fitting and thus saving on the associated expenditure.
4. When track maintenance is neglected for along time, it may render the track beyond repair calling for heavy track renewals that entail huge expenses.

- Gauging:

The gauge should be checked and an attempt should be made to provide a uniform gauge with in permissible tolerance limits.

2. Systematic Overhauling:

It should normally commence after the completion of one cycle of through packing. It involves the following operation sequence:

a. Shallow screening and making up ballast section.
b. Replacing damaged or fittings.
c. Including all items in through packing.
d. Making up the Cess * (tax).

3. Picking up slacks:-

Slacks are those points in the track where the running of trains is ~~faulty~~ faulty. Slacks are generally occurs in the following cases:-

a. Stretches of yielding formation.
b. Improperly aligned curves.
c. Portions of track with poor drainage.
d. Approaches to level crossing, girder bridges etc.

e. Section with an inadequate or unclean ballast cushion.

No through packing is done during the rainy season & slacks are only picked up enough to keep the track safe and in good running condition.

Duties of a Permanent Way Inspector (PWI)

The PWI is generally responsible for

a. Maintenance & inspection of the track to ensure satisfactory and safe performance.

b. Efficient execution of all works incidental to track maintenance, including track relaying work.

c. Accounts and periodical verification of the stores & tools in his or her charges.

d. Maintenance of land boundaries between stations and at important stations as may be specified by the administration.

- The PWI also carries out inspection of the following facts of a track:—

(a) Testing the track.

(b) Inspection of track and gauge.

(c) Level crossing inspection.

(d) Point and crossing inspection.

(e) Curve inspection.

(f) Safty of track.

- In addition to the inspection, a PWI also carries out following duties:—

a) Check the proximity of trees that are likely to damage the track and get them removed.

b) Check night patrolling at least once a month ~~by~~ by ~~train~~ trolley as well as train.

c) Takes the necessary safety measures while executing maintenance work that affects the safety of the track.

d) periodically inspects & respective LWR tracks to ensure there safety

e) Ensures the cleanliness of station yards.

f) Keeps proper records of the training out of ballast.

g) Looks after all establishment work, including the welfare of the staff working under his his charge and maintenance there service records.

h) Ensures the safety of the track during the execution of work that affects the track.

-: Introduction to Bridges :-

1. Bridge - A structure facilitating a communication route for carrying load traffic or other moving loads over a depression or obstruction such as river, stream, channel, road or railway. The communication route may be a railway track, a tramway, a roadway, a footpath, a cycle track or a combination of them.

2. High Level Bridge or Non-submersible bridge - The bridge which does not allow the flood waters to pass over them. All the flood water is allowed to pass through its vents. In other words it carries the roadway above the highest flood level of the channel.

3. Submersible bridge - A submersible bridge is a structure which allows flood water to pass over bridge submerging the communication route. Its formation level should be so fixed as not to cause interruption to traffic during floods for more than three days at a time nor for more than six times in a year.

4. Causeway - It is a pucca submersible bridge which allows floods to pass over it. It is provided on less important routes in order to reduce the construction cost of cross drainage structures. It may have vents for low water flow.

5. Culvert - When a small stream crosses a road with linear waterway less than about 6m, the cross drainage structure so provided is called culvert.

6. Apron - It is a layer of concrete, masonry stone etc. placed like flooring at the entrance or outlet of a culvert to prevent scour.

7. Curtain Wall - It is a thin wall used as a protection against scouring action of a stream.

8. Piers - They are the intermediate supports of a bridge superstructure and may be of solid or open type.

9. Abutments - They are the end supports of the superstructure.

10. Effective span - The centre to centre distance between any two supports is called as the effective span of a bridge.

11. Clear span - The clear distance between any two adjacent supports of a bridge is called clear span.

12. Economic span - The span for which the total cost of bridge structure is minimum is known as economic span.

13. Afflux - Due to construction of the bridge, there is a contraction in waterway. This results in rise of water level above its normal level while passing under the bridge. This rise is known as afflux.

14. Free board - Free board at any point is the difference between the H.F.L after allowing for afflux, if any, and the formation level of road embankment on the approaches or top level of guide bunds at that point.

15. Length of the bridge - The length of a bridge structure will be taken as the overall length measured along the centre line of the bridge from the end to end of the bridge deck.

16. Low Water Level (L.W.L) - The low water level is the level of water surface obtained generally in the dry season.

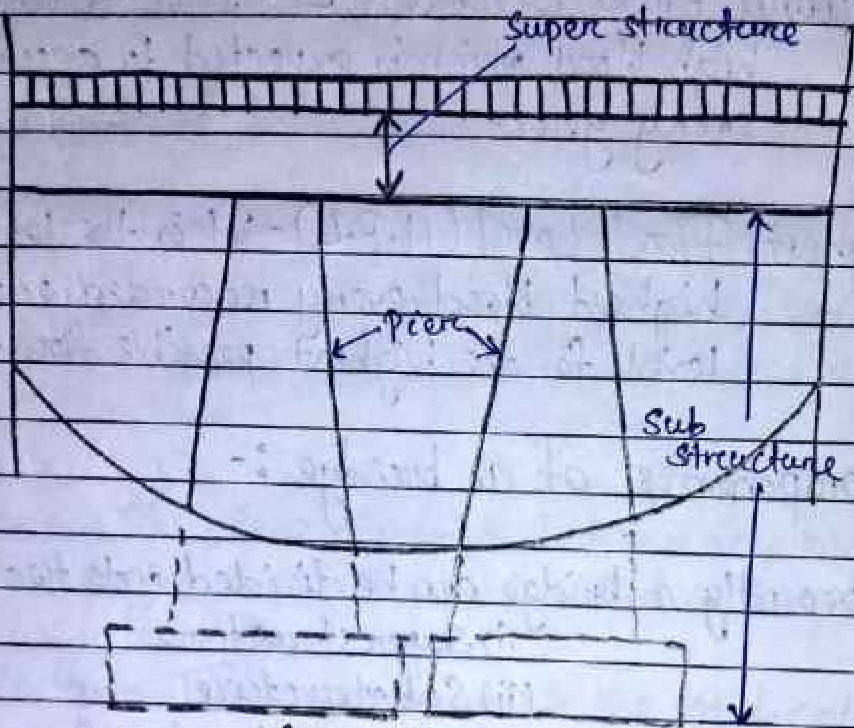
17. Ordinary Flood Level (O.F.L) - It is the avg. level of a high flood which is expected to occur normally every year.

18. Highest Flood Level (H.F.L) - It is the level of the highest flood every recorded or the calculated level for the highest possible flood.

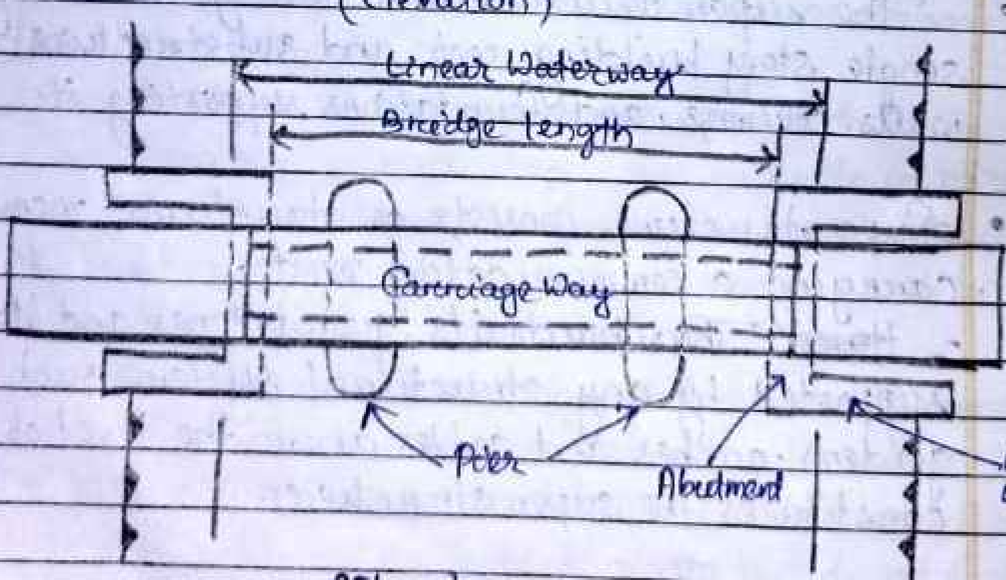
Components of a bridge :-

- Broadly a bridge can be divided into two major parts
  (i) Superstructure
  (ii) Substructure
- The superstructure of a bridge is analogous to a single story building roof and substructure to that of walls, columns, and foundations supporting it.
- Superstructure consists of structural members carrying a communication route.
  - ~~Hence~~ Thus, handrails, guard stones and flooring supported by any structural system such as beams, girders, arches and cables above the level of bearings constitutes the superstructure.
- Substructure is a supporting system for superstructure. It consists of the following (i) Abutments
  (ii) Piers and abutment piers
  (iii) Wing walls, and
  (iv) Foundations for the piers and abutments.

• The other main parts of bridge structure are approaches, bearings and river training works, like aprons, revetment for slopes at abutments etc.



(Elevation)



(Plan)

(Components of a bridge)

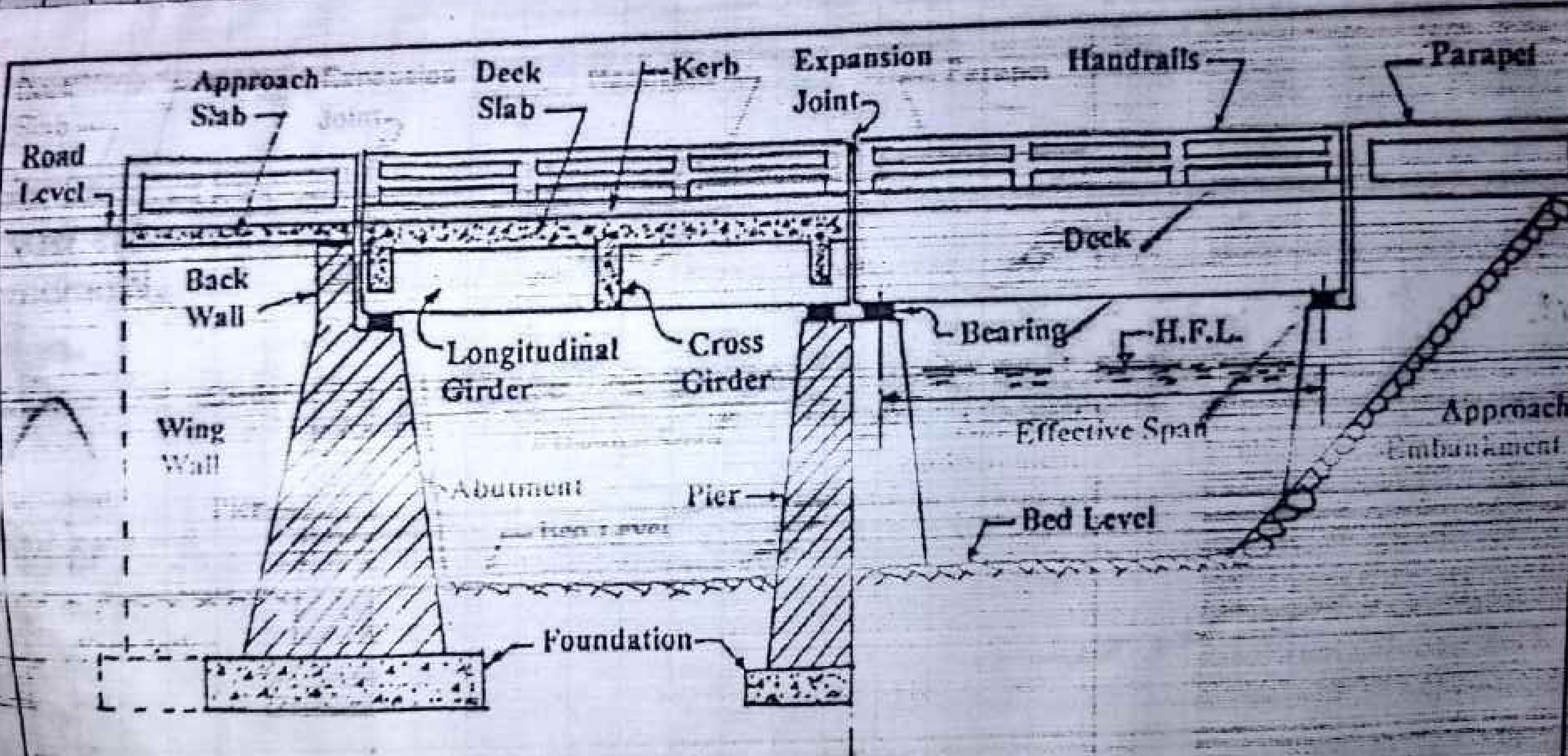


Figure 1: Components of a Typical Bridge.

Classification of bridges:-

- Bridges can be classified into various types depending upon the following factors:-

1. Materials used for construction :- (i) Timber bridges
   (ii) Masonry bridges
   (iii) Pre-stressed bridges
   (iv) Composit bridges
2. Alignment - (i) Straight bridge (ii) Skew bridge
3. Location of bridge floor - (i) Deck
   (ii) Semi-through or through bridges.
4. Purpose - (i) Aqueduct
   (ii) Viaduct
   (iii) Highway bridge
   (iv) Railway bridge
   (v) Foot bridge etc.
5. Nature of superstructure action - (i) Portal frame bridge
   (ii) Truss bridge
   (iii) Balanced Cantilever bridg
   (iv) Suspension bridges
6. Position of high flood level - (i) Submersible bridges
   (ii) Non-submersible bridges
7. Life - (i) Permanent bridges
   (ii) Temporary bridges
8. Loadings - (i) Class AA
   (ii) Class A
   (ii) Class B
9. Fixed or Movable - (i) Swinging bridges
   (ii) Bascule bridges
   (iii) Lift bridges
10. Span length - (i) Culverts — (Span less than 8m)
    (ii) Minor bridges (Span 8-30m)
    (iii) Major bridges (Span above 30m)
    (iv) Long span bridges (Span above 120m)

11. Degree of redundancy - (i) Determinate bridges
(ii) Indeterminate bridges.

12. Type of connection - (i) Pinned connected bridges
(ii) Riveted or Welded bridges.

1) Foot bridge - The foot bridge is a bridge exclusively used for carrying pedestrians, cycles and animals.

2) Deck bridges - These are the bridges whose floorings are supported at top of the super structures.

3) Through bridges - These are the bridges whose floorings are supported or suspended at the bottom of the superstructure.

4) Semi-through bridges - These are the bridges whose floorings are supported at some intermediate level of the superstructure.

5) Cantilever bridges - Bridges which are more or less fixed at one end and free at other end. It can be used for spans varying from 8 m. to 20 m.

6) Simple bridges - They include all beam, girder or truss bridges supported at both ends only. It is suitable for span up to 8 m.

7) Continuous bridges - Bridges which continue over two or more support spans. They are used for large spans and where unyielding foundations are available.

8) Arch bridges - These are the bridges which produce inclined pressure on supports under vertical loads. These bridges can be economically used up to spans about 20 m. The

arches may be in the barrel form or in the form of ribs.

9) Rigid frame bridges - In this bridges the horizontal deck slab is made monolithic with the vertical abutment walls. These bridges can be used up to span of about 20m. Generally this type of bridge is not found economical for spans less than 10 meters.

10) Square bridge - These are the bridges at right angles to the axis of the river.

11) Skew bridge - The bridges which are not at right angles to the axis of the river.

12) Suspension bridges - These are the bridges suspended on cables anchored at ends.

13) Under-bridges - It is a bridge constructed to enable a road to pass under another work or obstruction.

14) Over-bridges - It is a bridge constructed to enable one form of land communication over the other.

15) Class AA bridges - These are bridges designed for I.R.C class AA loading and checked for class A loading. They are provided within certain municipal limits, in certain existing or contemplated industrial area, in other specified areas and along certain specified highways.

16) Class A bridges - These are permanent bridges designed for I.R.C class A loading.

17) Class B bridges - These are temporary bridges designed for I.R.C class B loading.

Classification of bridges

- Permanent bridges
  - Stone masonry and plain C.C.
    - Causeway
    - Submersible
    - Arch
  - R.C.C bridges
    - Slab
    - Slab and beam
    - Arch
      - Fixed Barrel type
      - Open Spandral Ribbed arch
      - 2-hinged Arch
      - 3-hinged arch
      - Bow string Girder
    - Portal frame
    - Cantelever
  - Iron and steel
    - Girder
      - Parallel Flange Girder
        - Truss type
        - Plate type
      - Parabolic Girder
        - Truss type
        - Plate type
    - Suspension
      - Straight line type
      - Vertical Suspension type
      - Stiffened type
      - Combination
    - Movable
      - Swing
      - Bascule
      - Reflactile
      - Lift
      - Ferry
    - Cantilever
    - Composite type
    - Arch
      - 2-hinged
      - 3-hinged
      - Bow String Girder
  - Culverts
    - Brick, stone, R.C.C
      - Box type
      - Pipe
      - Arch
      - Slab
  - Prestressed Concrete
- Temporary bridges
  - Boat
  - Truss
  - Flying
  - Bridges on piles
  - Bridges on trestle
  - Bridges on cribs
  - Raft
  - Pantoon
  - Lift

Requirements of an ideal bridge:-

- An ideal bridge meets the following requirements to fulfil the three criteria of efficiency, effectiveness and equity
  (i) It serves the intended function with utmost safety and convenience.
  (ii) It is aesthetically sound.
  (iii) It is economical.

- The site characteristics of an Ideal bridge:-

1. The stream at the bridge site should be well defined and as narrow as possible.
2. There should be a straight reach of stream at bridge site.
3. The site should have firm, permanent, straight and high banks.
4. The flow of water in the stream at the bridge site should be in steady regime condition. It should be free from whirls and cross-current.
5. There should be no confluence of large tributaries in the vicinity of bridge site.
6. It should be reliable to have straight approach roads and square alignment, i.e. right-angled crossing.
7. In order to achieve economy there should be easy availability of labour, construction material and transport facility in the vicinity of bridge site.
8. There should be minimum obstruction of a natural waterway so as to have minimum afflux.
9. In order to have minimum foundation cost, the bridge site should be such that no excessive work is to be carried inside the water.
10. At bridge site it should be possible to provide

secure and economical approaches.

11. In case of curved alignment the bridge should not be on the curve, but preferably on the tangent since otherwise there is a greater like hood of accident as well as an added centrifugal force which increases the load effect on the structure and will require modification of design.

12. There should be no adverse environmental input.

13. The bridge site should be such that adequate vertical height and waterway is available.

14. Underneath the bridge for navigational use.

- In actual practice the determination of best possible site for any proposed bridge is truly an economic problem.
- The various factors which should be carefully examined before setting finally upon the layout of a bridge as follows:
  - (i) Grade on alignment
  - (ii) Geographical Conditions
  - (iii) Government requirements
  - (iv) Commercial influences
  - (v) Adjacent property consideration
  - (vi) General features of the bridge structure
  - (vii) Future trends for enlargement
  - (viii) Time consideration
  - (ix) Foundation Considerations
  - (x) Construction facilities available
  - (xi) Erection Consideration
  - (xii) Aesthetics
  - (xiii) Maintenance and repairs
  - (xiv) Environmental Impact
  - (xv) Stream characteristics
  - (xvi) Navigational considerations

Bridge Alignment :-

- Depending upon the angle which the bridge makes with the axis of the river, the alignment can be of two types:-

(a) **Skew Alignment** - In this the bridge is at some angle to the axis of the river which is not a right angle.

(b) **Square Alignment** - In this the bridge is at right angle to the axis of river.

- As far as possible, it is always desirable to provide the square alignment. The skew alignment suffers from the following disadvantages:

(i) A great skill is required for the construction of skew bridges. Maintenance of such type of bridges is also difficult.

(ii) The water pressure on piers in case of skew alignment is also excessive because of non-uniform flow of water underneath the bridge superstructure.

(iii) The foundation of a skew bridge is more susceptible to scour action.

- At certain locations to avoid costly and unsafe approaches it becomes essential to provide skew alignment.

On such locations, the following points are kept in mind.

(i) There should be smooth entry and exit of water underneath the skew bridge.

(ii) The skew alignment should not be curved. It is difficult to construct and maintain the curved bridge. The curved bridge has to resist an additional force due to centrifugal action. It is always desirable to arrange piers parallel to the axis of river.

Flood Discharge:-

- One of the essential data for the bridge design is fair assessment of the maximum flow which could be expected to occur at the bridges site during the design period of the bridge.
- The conventional practice in India for determination of flood discharge is to use a few convenient formulae or past records.

* This faulty determination of flood discharge which lead to failure of many hydraulic structures.

- As per I.R.C recommendation the maximum discharge which a bridge on a natural stream should be designed to pass, determined by the following methods:-

(a) From the rainfall and other characteristics of the catchment

(i) By use of an empirical formula applied to that region

or (ii) By a rational method, provided it is possible to evaluate for the region concerned, the various factors employed in the method.

(b) From the hydraulic characteristics of the stream such as cross-sectional area, and slope of the stream allowing for velocity of flow.

(c) From the records available, if any, of discharges observed on the stream at the site of the bridge, or at any other site vicinity.

Emperical Methods for Estimation of flood discharge in India:-

- Following are some of the most commonly used emperical method for flood estimation in India:-
  1) Dicken's Formula
  2) Ryve's Formula
  3) Inglis Formula
  4) Nawab Jang Bahadur's Formula
  5) Creager's Formula
  6) Khosla's Formula
  7) Besson's Formula

- In these methods area of a basin or a catchment is considered mainly.
- All other factors which influence peak flow are merged in a constant.
- A general equation may be written, in the form

$$\boxed{Q = C \cdot M^n}$$

Here,
- Q = Peak flow or rate of maximum discharge
- C = A constant for the catchment
- M = Area of the catchment, and 'n' is an index

- The constant for a catchment is arrived at, after taking the following factors into account:

(a) Basin characteristics
- (i) area
- (ii) Shape
- (iii) Slope

(b) Strom characteristics.

(i) intensity

(ii) duration

(iii) distribution

Limitations :-

1. These methods do not take frequency of blood into consideration
2. These methods cannot be applied universally.
3. Fixing of constant is very difficult and exact theory cannot b put forth for its selection.

- However, they give fairly accurate idea about the peak flow for the catchment they represent.

1) Dicken's formula :-

- It was formerly adopted only in Northen India but now it can be used in most of the states in India after proper modification of the constant.

$$\boxed{Q = C \cdot M^{3/4}}$$

Here,

Q = Discharge in m^3/sec

M = Area of catchment in sq.km

C = Constant

According to the area catchment and amount of rainfall, 'C' varies from 11.02 to 22.04.

Region	Value of C
Northen India	11.37
Central India	13.77-19.28
Western India	22.04

2) Ryve's formula :-

- This formula is used only in Southern India.

$$\boxed{Q = C \cdot M^{2/3}}$$

Here,

Q = Discharge in cum/sec

C = 6.74 for area within 24 km from coast

= 8.45 for areas within 24-161 km from coast

= 10.1 for limited hilly areas

In worst cases it is found that value of 'C' goes up to 40.5.

3) Inglis formula :-

- This formula is used only in the state of Maharashtra.
- Here three different cases are taken in to consideration.

(a) For small areas only (It is also applicable for fan-shaped catchment)

$$\boxed{Q = 123.2\sqrt{M}}$$

(b) For areas between 160 to 1000 square km.

$$\boxed{Q = 123.2\sqrt{M} - 2.62(M - 259)}$$

(c) For all types of catchments

$$\boxed{Q = \frac{123.2M}{\sqrt{M + 10.36}}}$$

In all equations 'M' is area in km^2

4) Nawab Jang Bahadur's formula :-

$$\boxed{Q = C\left(\frac{M}{2.59}\right)(a - b.\log A)}$$

Here,

a, b and C are constant.

$a = 0.993$

$b = 1/14$

$C = 59.5$ for North India

$= 48.1$ for South India

5) Creager's formula:-

- This method was given formerly by Creager, Justin and Hinds in U.S.A.
- From the past records a graph is plotted between peak flow per square km of the basin and the basin area for various values.
- The points obtained on the graph are joined by an envelope curve. The equation of the curve is of the type:

$$\boxed{q = C \cdot M^{n}}$$

Here

q = the peak flow per sq. km of a basin

M = the catchment area in km^2

n = Some index

- By multiplying both sides of the above equation area of the basin M, we get

$$\boxed{Q = C \cdot M^{n+1}}$$

Where,

Q = Peak flow

Equation given by Creager, Justin and Hinds is

$$\boxed{Q = 46 \cdot CM^{(0.894M - 0.048)}}$$

6) Khosla's formula :-

- It is a rational formula. It is based on the equation

$$\boxed{\begin{array}{c} P = R + L \\ \text{or} \quad R = P - L \end{array}}$$

Here,

R = Runoff

P = Rainfall

L = Losses

- According to Mr. Khosla main factor influencing losses is temperature.
- He expressed losses in mean temperature, T_m in Fahrenheit.
- The formula in C.G.S system is given below

$$\boxed{L = 4.28\, T_m}$$

Where,

L is in mm, T_m is Centigrade

$$\boxed{R = P - 4.28\, T_m}$$

- The above mentioned formula of losses can be used for the values of temperature less than 40°F.
- For lower temperature he gave the following table:

T_m °F	40	30	20	10	0
L inches	0.84	0.70	0.60	0.50	0.40

- Khosla formula is useful in assessing water potential for a basin in river valley project.

7) Besson's formula :-

- This formula is very rational and can be used in any case

$$\boxed{Q_m = \frac{P_m \times Q_r}{P_r}}$$

Here,

Q_m = Peak flow expected

Q_r = Some observed peak flow

P_r = Observed rainfall

P_m = Expected rainfall

Rational Methods for Estimation of Flood Discharg

- This method is applicable for determination of flood discharge for small culverts only.
- In order to arrive at a rational approach, a relationsh has been established between rainfall and runoff under various circumstances.
- The size of the flood depends upon the following factors:

(i) Climate or Rainfall factors, this includes

(a) intensity

(b) distribution.

(c) duration of rainfall

(ii) Catchment Area factors, this includes

(a) Catchment area

(b) its shape

(c) its slope

(d) porosity of the soil

(e) vegetable cover

(f) initial state of ~~wet~~ wetness

Waterway:-

- The area through which the water flows under a bridge superstructure is known as the waterway of the bridge.
- The linear measurement of this area along the bridge is known as the linear waterway.
- This linear waterway is equal to the sum of all the clear spans. This may be called as artificial linear waterway.
- The natural waterway is the unobstructed area of the river or stream through which the water flows at the bridge site.

★ **Linear waterway:-** The linear waterway of a bridge shall be the length available in the bridge between extreme edge of a water surface at the highest flood level, measured at right angles to the abutment faces.

★ **Effective Linear waterway:-** Effective linear waterway is the total width of waterway of the bridge minus the effective width of obstruction.

[For calculating the effective linear waterways, the width of mean obstruction due to each pier shall be taken as the mean submerged width of the pier at its foundation up to the maximum scour level. The obstruction at the ends due to the abutments or pitches slopes should be ignored.]

Economic Span:-

- The economic span of a bridge is the one which reduces the overall cost of a bridge to be a minimum.
- The overall cost of a bridge depends upon the following factors:
  - (i) Cost of material and its nature
  - (ii) Availability of skilled labour
  - (iii) Span length
  - (iv) Nature of stream to be bridged

(v) Climatic and other conditions:

- It is not in the hands of engineers to bring down the cost of living index or the price of the materials like cement, steel, timber etc. but they can help in bringing down the cost of bridges by evolving economical designs.
- Considering only the variable items, the cost of superstructure increases and that of the sub-structure decreases with an increase in the span length.
- Thus most economic span length is that, which satisfies the following, i.e.

The cost of the super-structure = The cost of the sub-structure

Afflux :-

- When a bridge is constructed, the structures such as abutment and piers cause the reduction of the natural waterway area.
- The contraction of the stream is desirable because it leads to tangible saving in the cost specially for alluvial streams whose natural surface width is too large than required for stability.
- Therefore, to carry the maximum flood discharge, the velocity under the bridge increases. This increased velocity gives rise to a sudden heading up of water on the upstream side of the stream.
- This phenomenon of heading up of water on the upstream side of the stream is known as "afflux."
- Greater the afflux, greater will be the velocity under the downstream side of the bridge and greater will be the depth of scour and consequently greater will be the depth of foundations required.

The afflux is calculated by one of the following formula:-

(a) Marriman's formula:-

$$h_a = \frac{V^2}{2g}\left\{\left(A/Ca\right)^2 - \left(A/A_1\right)\right\}$$

Here,

h_a = Afflux in meters
V = Velocity ~~in~~ of approach in m/s
A = Natural waterway area at the site
a = Contracted area in m^2
A_1 = The enlarged area upstream of the bridge m^2
C = Co-efficient of discharge
$= 0.75 + 0.35(a/A) - 0.1(a/A)^2$ approximately

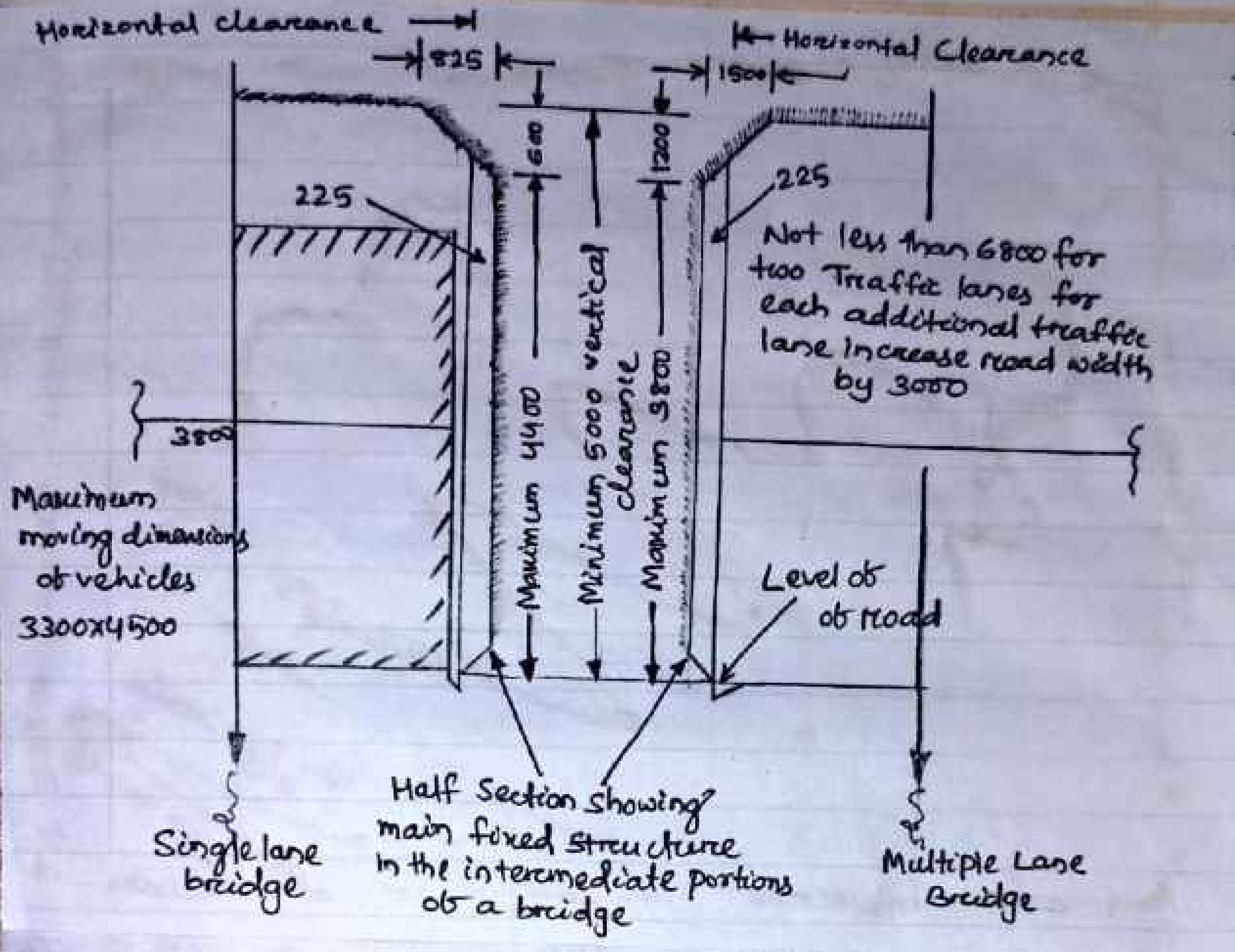
(b) Molesworth's formula:-

$$h_a = \left[\frac{V^2}{17.9} + 0.015\right]\left\{(A/a)^2 - 1\right\}$$

Here,
'V','A' and 'a' have same meaning as in the Marriman's formula.

Clearance :-

- To avoid ~~the~~ any possibility of traffic striking any structural part clearance diagram are specified.
- The horizontal clearance should be the clear width and the vertical clearance the clear height, available for the passage of vehicular traffic as shown in the clearance diagram below:-



(Clearance diagram for road bridges)

→ For a bridge constructed on a horizontal curve with super-elevated road surfaces, the horizontal clearance should be increased on the side of inner kerb by an amount equal to 5m multiplied by the superelevation. The minimum vertical clearance should be measured from the super elevated level of roadway.

Free board :-

→ Free board is the vertical distance between the designed high flood level, allowing for the afflux, if any, and level of the crown of the bridge at its lowest point.

→ It is essential to provide the free board in all types of bridges for the following reasons:

(i) Free board is required to allow floating debris, fallen tree trunks and approach waves to pass under the bridge.

(ii) Free board is also required to allow for the afflux during the maximum flood discharge due to contraction of waterway.

(iii) Free board is required to allow the vessels to cross the bridge in case of navigable rivers.

→ The value of the free-board depends upon the type of the bridge

Sl.No	Type of bridge	Free board
1.	High level bridges	600mm
2.	Arch bridges	300mm
3.	Girder bridges	600 to 900mm
4	Navigational streams	2400 to 3000mm

Collection of Bridge Design Data:-

- For a complete and proper appreciation of the bridge project the engineer in charge of the investigation should carry out studies regarding its financial, economical, social and physical feasibility.
- The detailed information to be collected may cover loading to be used for design based on the present and anticipated future traffic, hydraulic data based on stream characteristics, geological data, subsoil data, climatic data, alternative sites, aesthetics, cost, etc.
- The following drawings containing information as indicated

should be prepared

1. Index map
2. Contour survey plan
3. Site plan
4. Cross-section
5. Longitudinal Section
6. Catchment Area map
7. Soil-profile

Design data for major bridge:-

A.- General data:-

1. Name of the road and its classification
2. Name of the stream
3. Location of the nearest G.T.S. benchmark and
4. Chainage at centre line of the stream
5. Existing arrangement for crossing the stream.
   (a) During monsoon
   (b) During dry season
6. Liability of the site to earthquake disturbances.
   capacity

B.- Catchment area and Runoff data:-

1. Catchment area
   (a) Hilly area (b) In plains
2. Maximum recorded intensity and frequency of rainfall in catchment
3. Rainfall in centimeters per year in the region
4. Length of catchment in kilometers
5. Width of catchment in kilometers
6. Longitudinal slope of catchment
7. Cross slope of catchment
8. Nature of catchment and its shape

C. Data regarding nature of stream
D. Data regarding alignment and approaches
E. Superstructure data
F. Foundation data
G. Data of existing structure
H. Miscellaneous data

Sub-surface investigation :-

→ Sub-surface investigation is essential for to know the properties of the bridge site soil. The field and laboratory investigations required to obtain the necessary soil data for the design are called soil exploration.

→ The principal requirements of a complete investigation can be summarised as follows:
1. Nature of the soil deposits up to the sufficient depth
2. Depth, thickness and composition of each soil stratum
3. The location of ground water
4. Depth to rock and composition of rock
5. The engineering properties of soil and rock strata that affect the design of the structure.

→ In exploration programme the extent of distribution of different soils both in the horizontal and vertical directions can be determined by the following methods:
1. By use of open pits
2. By making bore holes and taking out samples
3. By soundings
4. By use of geophysical methods

Advantages of Sub-surface Investigation :-

- There are a lot of advantages of carefully planned investigation programme. These can be summarized as below:-

1. A suitable and economical solution can be worked out.
2. The construction schedule can be properly planned.
3. The extent and nature of difficulties likely to be meet with can be determined.
4. The rate and amount of settlements can be determined.
5. The variation in the water-table, the presence of artesian pressures can be found out.

Bridge Foundation

Scour depth :-

- When the velocity of stream exceeds the limiting velocity which the erodable particle of bed material can stand, the scour occurs.
- The normal scour depth is the depth of water in the middle of the stream when it is carrying the peak flood discharge.
- This can be easily ascertained by actual sounding at or near the site proposed for the bridge during or immediately after a flood before the scour holes have had time to silt up appreciably.
- Due allowance should be made in the observed depth for increase in scour resulting from:

(i) The designed discharge being greater than the flood discharge during which the scour was observed.

(ii) The increase in velocity due to the obstruction in flow caused by construction of the bridge.

- The scour pattern at a bridge depends upon factors like flood discharge, bed slope, direction of flow, bed material, alignment of pier, pier geometry i.e. its shape and size etc.
- For safe and sound design of a bridge it is important to estimate the correct scour depth.
- Where the practical method of determining a scour is not possible the following theoretical methods may be used to different types of streams:-

(1) Scour depth of alluvial Streams :-

- Alluvial streams bed and banks are composed of loose granular material, that has been deposited by the stream and can be picked up and transported again by the current during flood.

• These streams tend to scour or silt up till it has acquired such a cross-section and more particularly such a slope that the resulting velocity is 'non-silting' and 'non-scouring'.

• When such a stage occurs the stream becomes stable and tends to maintain the acquired shape and size of its cross-section and the acquired slope. Such a stream is known as 'regime channel'.

• The alluvial stream when comes to regime it acquires a regime wetted perimeter 'P', a regime slope 'S' and a regime hydraulic mean depth 'd'.

• As a result of this it will have a fixed area of cross section and a fixed velocity 'V'.

• Lacy developed following equations for these regime characteristics of an alluvial channel carrying a discharge of 'Q' in cum/sec.

$$\boxed{P = 4.8\sqrt{Q}}$$

$$\boxed{d = 0.473\left(\frac{Q}{f}\right)^{1/3}}$$

$$\boxed{S = \frac{0.0003 f^{5/3}}{Q^{1/6}}}$$

$$\boxed{V = 0.44\, Q^{1/6} f^{1/3}}$$

$$\boxed{A = \frac{2.3\, Q^{5/6}}{f^{1/3}}}$$

• The scour depth can be calculated as given below in case-I and case-II.

Case-I - Linear Waterway of the bridge is not less than the regime width :-

- In this case the normal scour depth is equal to the regime depth given by the following the Lacy's regime equation.

$$d = 0.473\left(\frac{Q}{f}\right)^{1/2} \quad \text{——— (1)}$$

Here

d = Normal depth of scour below H.F.L for Regime conditions in a stable channel (in meters)
Q = The designed discharge in m^3/sec
f = Lacey's silt factor for a representative sample of the bed material
$= 1.76\sqrt{m}$, here 'm' is the mean diameter of the bed material in mm.

- The values of 'f' normally recommended for various grades as per the following table:-

Sl No	Type of bed material to which applicable	Mean dia. of particle in mm	Value of f
1.	Very fine silt	0.052	0.400
2.	Fine silt Godavary Western India	0.081	0.500
3.	Fine silt	0.120	0.600
4.	Fine silt Krisna Western Delta type	0.158	0.700
5.	Medium silt	0.233	0.850
6.	Standard silt	0.323	1.000
7.	Medium Sand	0.505	1.250
8.	Coarse Sand	0.725	1.500
9.	Fine bajri and Sand	0.988	1.750
10.	Heavy Sand	1.290	2.000

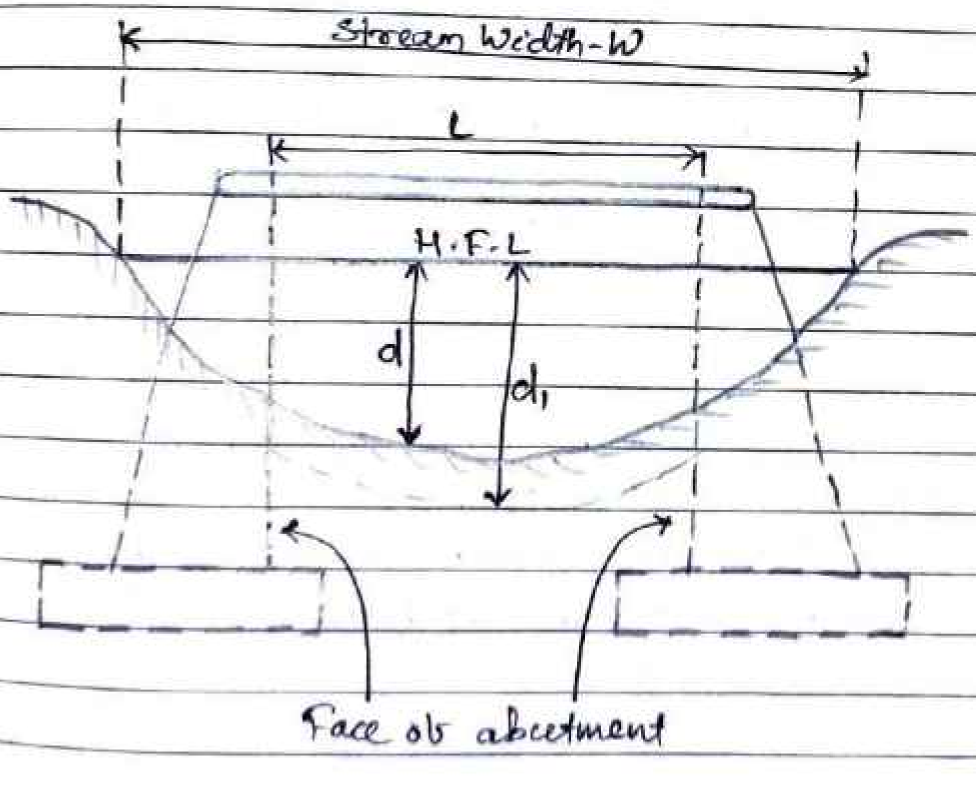
Case-II - Lineare Waterway less than the Regime Width:-

- In this case of the normal scour depth under the breidge can be given by the following equation:-

$$d_1 = d\left(\frac{W}{L}\right)^{0.61} \quad \text{———— (2)}$$

Here,

W = The regime width of the stream
L = The waterway provided under the breidge
d = The normal scour depth when L = W
d_1 = The normal scour depth with contracted waterway



(2) Scour depth for Quasi-Alluvial Streams:-

- In quasi-alluvial stream which have got rigid banks and erodable beds, the normal scour depth when the stream width is large as compared to depth can be determined follows:-

(i) When velocity is known

$$d = \frac{Q}{W \cdot V} \quad \text{———} \quad (3)$$

Here,

W = The surface width of the stream
V = Velocity of flow

(ii) When slope is known

$$Q = \frac{1.0}{n} W \cdot d^{5/3} S^{1/2} \quad \text{———} \quad (4)$$

Here,

n = Manning's coefficient
S = Slope

(iii) When both velocity and slope are not known

$$d = \frac{1.2 Q^{0.60}}{f^{0.33} \times W^{0.60}} \quad \text{———} \quad (5)$$

Here,

f = Silt factor

- Normal scour depth in case of quasi-alluvial streams for contracted waterway can be given by the eq^n (2).
- The maximum scour depth is not uniform even in straight reaches for natural streams.
- Table below gives the maximum scour depth under different conditions of flow:-

Sl No	Condition of flow	Max^m Scour Depth, dm
1.	In straight reach	1.27d
2.	At a moderate bend	1.50d
3.	At a severe bend	1.75d
4.	At right angled bend	2.00d
5.	At noses of piers	2.00d
6.	At upstream noses of guide banks	2.75d

- It has been observed that the maximum scour in case of abutment occurs at U/s corner, while in the case of a pier, it occurs at the D/s end.
- Due ~~to~~ allowance should be made in the calculated depth of scour for increase in scour resulting from possible concentration of flow through a portion of the waterway.
- In case of bridges causing contraction, the maximum scour depth should neither be less than the values indicated above nor the values obtained by the following formula:

$$d_m = d\left(W/L\right)^{1.56}$$

Here,

d_m = Max^m scour depth.

Depth of foundation:-

+ The depth of bridge foundation is determined by consideration of the safe bearing capacity of the soil after taking in to account the effect of scour.
+ In all doubtful cases, the bearing capacity of the foundation soil is ~~asce~~ ascertained by actual field load tests.
+ The bore holes are driven to determine the adequacy of thickness of the foundation bearing layer of the soil.
+ The minimum depth of foundation can be approximately calculated by the following relationship

$$h = \frac{P}{W}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

Here,

h = The depth of foundation in metres

P = The bearing capacity of soil in kg/m^2

W = The specific weight of earth in kg/m^2

ϕ = The angle of internal friction of the soil

Cohesionless Soil

Sl. No	Description	Safe bearing Capacity (t/m^2)
1.	Gravel, sand and gravel compact and offering high resistance to penetration when excavated by tools	45
2.	Coarse sand, compact and dry	45
3.	Medium Sand, Compact and dry	25
4.	Fine sand, silt (dry lumps) easily pulverised by the finger	15
5.	Loose gravel or sand gravel mixture: loose, Coarse to medium sand dry	25
6.	Fine Sand, loose and dry	10

Cohesive Soil

Sl. No	Description	Safe bearing Capacity (t/m^2)
1.	Soft shale, hard or stiff clay in deep bed, dry	45
2.	Medium clay readily indented with a thumb nail	25
3.	Moist clay and sand clay mixture which can be indented with strong thumb pressure	15
4.	Soft clay indented with moderate thumb pressure	10
5.	Very soft clay which can get penetrated several cm with the thumb	5
6.	Black cotton soil or other shrinkable or expansive clay in dry condition (50% saturated)	15

Bridge Foundation:-

+ A foundation is the part of the structure which is in direct contact with the ground.
+ It transfers the load of the structure to the soil below.
+ Before deciding upon its size, we must ensure that:

(i) The bearing pressure at the base does not exceed the allowable soil pressure.
(ii) The settlement of foundation is within reasonable limits.
(iii) Differential settlement is to limited as not to cause any damage to the structure.

+ Broadly, foundation may be classified under two categories

i.e. 1. Shallow foundation
2. Deep foundation

Shallow foundation:- According to Terzaghi, a foundation is said to be shallow if its depth is equal or less than its width.

Deep foundation:- According to Terzaghi, a foundation is said to be deep, the depth is greater that its width and it cannot be prepared by open excavation.

Types of Bridge Foundation:-

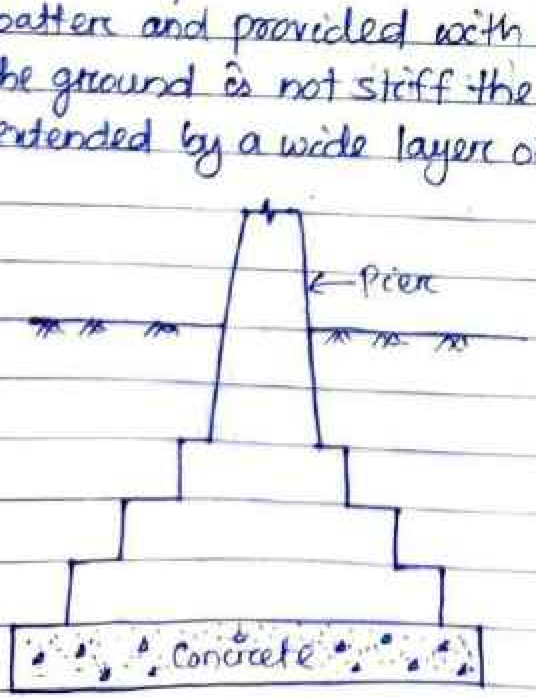
- The selection of foundation type suitable for a particular site depends on the following considerations:-

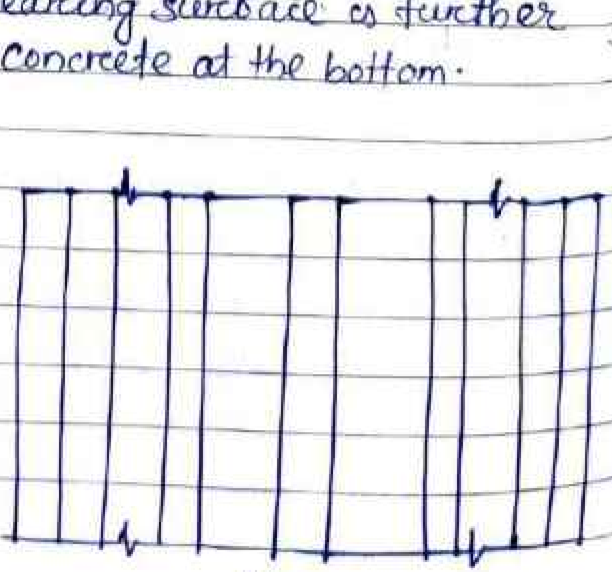
(1) Nature of subsoil
(2) Nature and extent of difficulties, e.g. presence of boulder, buried tree trunks, etc. Likely to be met with, and
(3) Availability of expertise and equipment.

- Depending upon their nature and depth, bridge foundation can be categories as follows:
  i. Open foundation
  ii. Raft foundation
  iii. Pile foundation
  iv. Well foundation

(i) Open foundation in Bridges:-

1) An open foundation or spread foundation is a type of foundation and can be laid using upon excavation by allowing natural slopes on all sides.
2) This type of foundation is practicable for a depth of about 5m and is normally convenient above the water table.
3) The base of the pier or abutment is enlarged or spread to provide individual support.
4) Since spread foundations are constructed in open excavation, therefore, they are termed as open foundation.
5) This type of foundation is provided for bridges of moderate height built on sufficiently firm dry ground.
6) The piers in such cases are usually made with a slight batter and provided with footings widened at bottom. Where the ground is not stiff the bearing surface is further extended by a wide layer of concrete at the bottom.





Plan

(ii) Raft foundation in Bridges :-

1) A raft or mat is a ~~combination~~ combined footing that covers the entire area beneath a bridge and supports all the piers and abutments.

2) When the allowable soil pressure is low, or bridge loads are heavy, the use of spread footing would cover more than one-half of the area, and it may prove more economical to use raft foundation.

3) They are also used where the soil mass contains compressible lenses so that the differential settlement would be difficult to control.

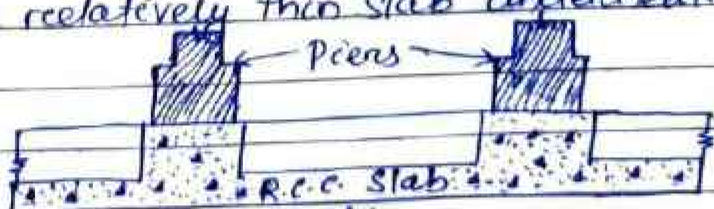
4) The raft tends to bridge over the erratic deposits and eliminates the differential settlement.

5) Raft foundation is also used to reduce the settlement above highly compressible soils by making the weight of bridge and raft approximately equal to the weight of soil excavated.

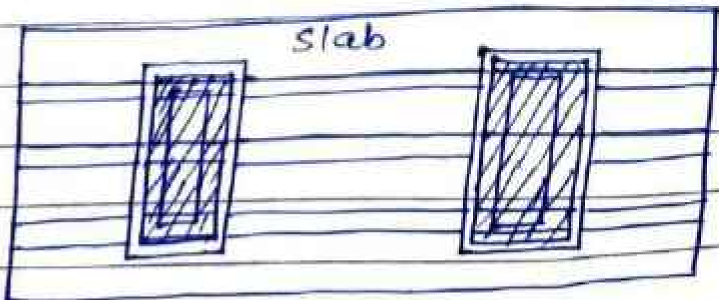
6) A raft may undergo large settlements without causing harmful differential settlement.

7) For this reason, almost double the settlement of that permitted for footings is acceptable for rafts.

8) Usually when hard soil is not available within 1.5 to 2.5m a raft foundation is adopted. The raft is compressed of reinforced concrete beams with a relatively thin slab underneath.



L-section



Plan

(iii) Pile foundations in bridges :-

1) The pile foundation is a construction for the foundation of a bridge pier or abutment supported on the piles.

2) A pile is an element of construction composed of timber, concrete or steel or a combination of them.

3) Pile foundation may be defined as a column support type of foundation which may be cast-in-situ or precast.

4) The piles may be placed separately or they may be placed in the form of a cluster throughout the length of the pier or abutment.

5) This type of construction is adopted when the loose soil extends to great depth.

6) The load of the bridge is transmitted by the piles to hard stratum below or it is resisted by the friction developed on the sides of piles.

Classification of piles :-

- Piles are broadly classified into two categories
  - (i) Classification based on the function
  - (ii) Classification based on materials and composition

(i) Classification based on function

- (a) Bearing Pile
- (b) Friction Pile
- (c) Screw Pile
- (d) Compaction Pile
- (e) Uplift Pile
- (f) Batter Pile
- (g) Sheet Pile.

(iii) Classification based on Materials and Composition
(a) Cement concrete piles
(b) Timber piles
(c) Steel piles
(d) Sand piles
(e) Composite piles

(iv) Well foundation in bridges :-

1) Well foundations are commonly used for transferring heavy loads to deep strata in river or sea bed for bridges transmission towers and harbour structures.

2) The situation where well foundations are resorted are as below

- Wherever consideration of scour or bearing capacity require foundation to be taken to depth of more than 5m below ground level, open foundation becomes uneconomical.
- Heavy excavation and dewatering problem coupled with effort involve in retaining the soil makes the open foundation costlier in comparison to other type of foundation.

3) Soil becomes loose due to excavation around the open foundation and hence susceptible to scouring. This is avoided in well foundation which is sunk by dredging inside of the well.

4) From bearing pressure considerations, a well foundation can always be left hollow thereby considerably reducing bearing pressure transmitted to the foundation material.

5) This is very important in soils of poor bearing capacity particularly in clayey soils.

6) In other type of foundation, the soil displayed is occupied by solid masonry/concrete which are heavier than the soil displayed and hence this does not give any relief in respect of adjusting bearing capacity.

7) However in case of well foundation this is easily achieved because of cellular space left inside the well.

Caissons :-

- The caisson is a structure used for the purpose of placing a foundation in correct position under water.
- The term caisson is derived from the French word 'caisse' meaning a box.
- It is a member with hollow portion, which after installing in place by any means is filled with concrete or other material.
- Caissons are preferred in sandy soils. The caissons can be divided in the following three groups:
  - (i) Box caissons
  - (ii) Open caissons or wells
  - (iii) Pneumatic caissons

(i) Box Caissons :-

- A box caisson is a strong watertight vessel open at top and close at the bottom.
- They are generally built of timber, reinforced concrete or steel.
- This type of caisson is suitable where bearing stratum is available at shallow depth, and where loads are not very heavy.
- To place the caisson in position, it is launched and floated to pier site where it is sunk in position.

(ii) Open caissons or wells :-

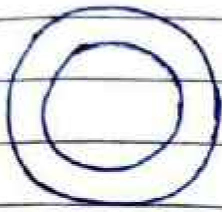
- The open caissons are open both at the top and the bottom.
- They are used on sandy or soft bearing stratum liable to scour and where no firm bed is available for large depth below the surface.
- They are generally built of timber, metal, reinforced

concrete or masonry.

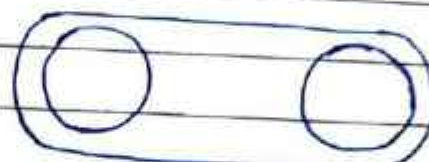
- They form the most common type of deep-foundations for bridges in India.

Shapes of well :-

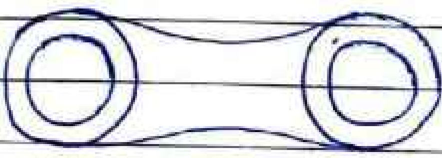
- The shapes of wells may be circular, rectangular, Double-D, rectangular with D-shaped ends, twin hexagonal and twin octagonal.



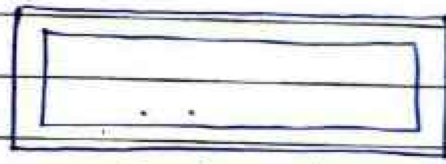
circular



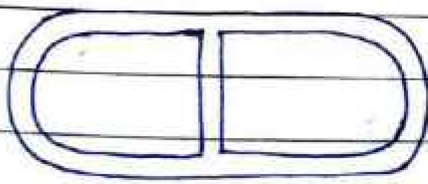
Twin- circular



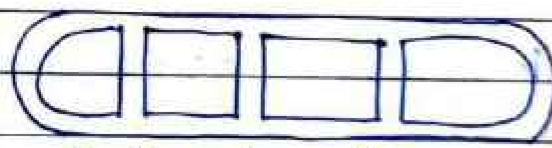
Dumb-



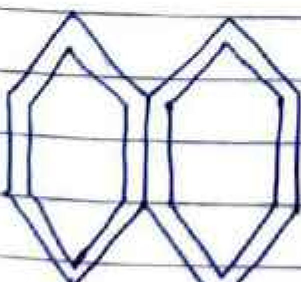
Rectangular



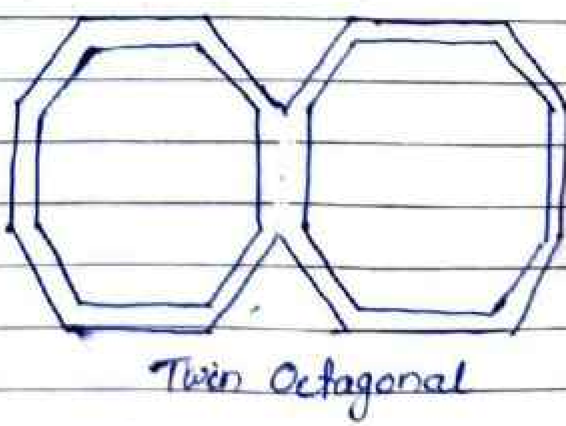
Double-D



Rectangular with D-shaped ends



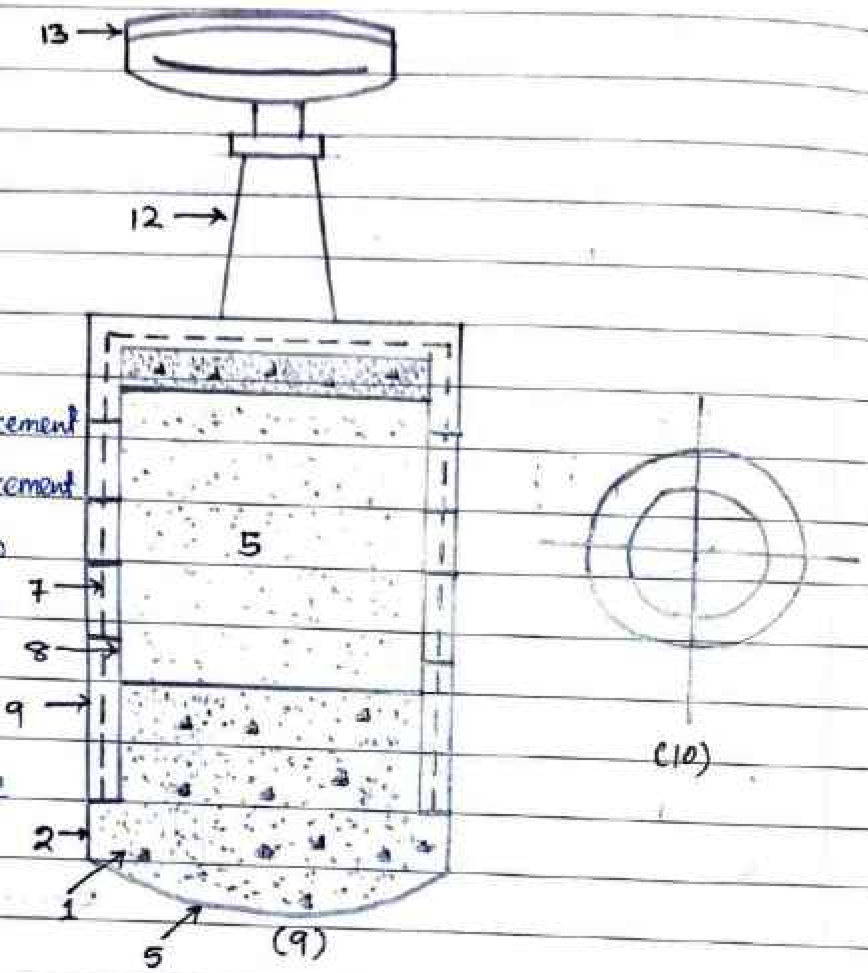
Twin hexagonal



Twin Octagonal

Well Components and their functions:-

1. Cutting edge
2. Curb
3. Steining
4. Bottom Plug
5. Filling
6. Top plug
7. Vertical Reinforcement
8. Horizontal Reinforcement
9. Vertical Section
10. Horizontal Section
11. Well Cap
12. Sub-structure
13. Superstructure



1. **Cutting edge** - It provides a comparatively sharp edge to cut the soil below during sinking operation. It usually consists of a mild steel equal angle of side 150mm.

2. **Curb** - It has a two fold purpose. During sinking it acts as an extension of cutting edge and also provides support to the well steining and bottom plug while after sinking it transfers the load to the soil below. It is made up of reinforced concrete using controlled concrete of grade M20.

3. **Steining** - It is the main body of the well. It also serves dual purpose. It acts as a cofferdam during sinking and a structural member to transfer the load to the soil below afterwards. The steining may consist of brick masonry and reinforced concrete. The thickness of steining

should not be less than 4.5 cm nor less than that given by equation

$$t = K\left(\frac{H}{100} + \frac{D}{100}\right)$$

Here,

t = minimum concrete steining thickness
H = Well depth below bed
D = External diameter of well
K = a constant which is 1.0 for sandy strata.
1.1 for soft clay
1.25 for hard clay
1.3 for hard soil with boulder

The brick steining should be about 10cm more than that for the corresponding concrete staining.

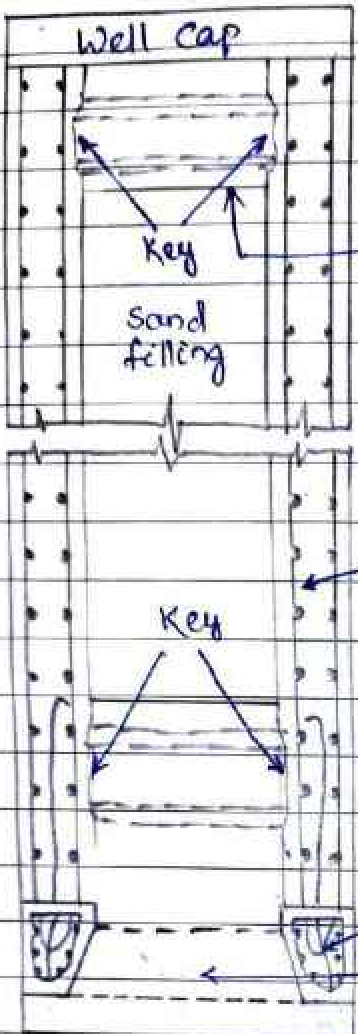
4. **Bottom Plug** - Its main function is to transfer load from the steining to the soil below.

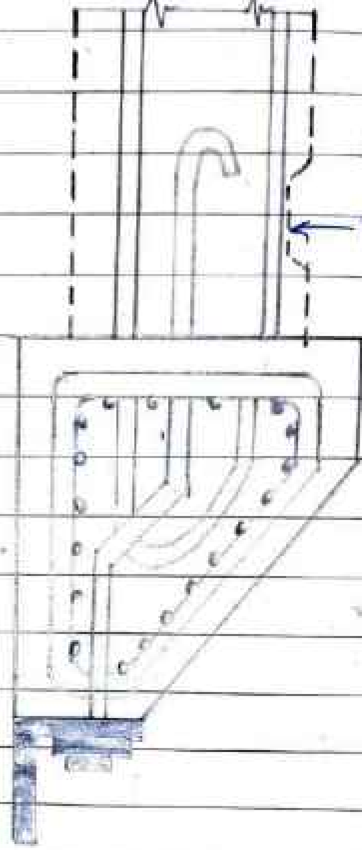
5. **Sand filling** - Its utility is doubtful. It is supposed to afford some relief to the steining by transferring directly a portion of load from well cap to the bottom plug.

6. **Top plug** - The opinion is divided about the top plug. It, at least, servers as a shuttering for laying well cap

7. **Reinforcement** - It provides requisite strength to the structure during sinking and service.

8. **Well Cap** - It is needed to transfer the loads and moments from the pier to the well or wells below. The shape of the well cap is similar to that of the well with a cantilevering of about 15cm. Whenever 2 or 3 wells of small diameter are needed to support the sub-structure, the well cap should be extended to cover the wells. The well cap is designed as a slab resting over the well or wells with partial fixity at the edges of the wells.





(Details of well foundation)

Depth of Well foundation :-

- As per I.R.C. Bridge Code (Part III) the depth of well foundation is to be decided on the following considerations:

(i) The minimum depth of foundation below H.F.L should be '1.33D', where 'D' is the anticipated maximum depth of scour below H.F.L. Depth should provide proper grip accord-ing to some rational formula.

(ii) The maximum bearing pressure on the sub-soil under the foundation resulting from any combination of loads and forces except wind and seismic forces should not exceed the safe bearing capacity of the subsoil, after taking in to account the effect of scour.

With ~~wind~~ wind and seismic forces in addition the max.

bearing pressure should not exceed the safe bearing capacity of the subsoil by more than 25%.

(iii) While calculating max. bearing pressure on the foundation bearing layer resulting from the worst combination of direct forces and overturning moments, the effect of a passive resistance of the earth on sides of the foundation superstructure may be taken into account below the max. depth of the scour only.

(iv) The effect of skin friction may be allowed on the portions below the max. depth of scour. Accordingly for deciding the depth of well foundation, we require correct estimation of the following

1. Maximum Scour depth
2. Safe bearing capacity
3. Skin friction
4. Lateral earth support below max. scour level.

- It is always desirable to fix the level of a well foundation on a sandy strata with adequate bearing capacity. When even a thin stratum of clay occuring between two layers of sand is met with, in that case well must be pierced through the ~~clay~~ clayey strata. If at all foundation has to be laid on clayey layer it should be ensured that the clay is stiff.

Design loads and forces :-

- The forces acting on a bridge structure, to be considered for the design of a well foundation are as follows

Vertical

(i) Dead load
(ii) Live load
(iii) Bouyancy

Horizontal

(i) Wind force

(ii) Force due to water currents

(iii) Longitudinal forces caused by the tractive effort of vehicle or by breaking effort of vehicle.

(iv) Longitudinal force on account of resistance of the bearing against movement due to variations of temperature.

(v) Seismic force

(vi) Earth pressure

(vii) Centrifugal force.

- The I.R.C Bridge Code II stipulates the magnitude of above loads and forces. The magnitude, direction and point of application of all the above forces can be resolved in to two horizontal forces, 'P' and 'Q' and a single vertical force 'W' under the worst possible combinations.